COHO SALMON HABITAT WITHIN BLACK CREEK, VANCOUVER ISLAND

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PREFACE

This is the second paper of a study designed to address the objectives of the Sustainable Fisheries Program within the Action Plan on Fish Habitat (Environmental Analysis). The Sustainable Fisheries Program provides the opportunity to assess land use patterns, examine productive capacity of various habitat types, obtain some new ecological knowledge, and develop the methodologies required to manage fisheries habitat. Guidelines, methodologies, inventory information, maps, and ecological knowledge developed during this study will assist the Coho Initiative: Comox Valley Habitat Pilot Project in fulfilling its goal of protecting and restoring wild coho salmon populations and their habitat. Mel Sheng (Fisheries and Oceans Canada) provided funding for 1996 and 1997 fry enumeration.

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ABSTRACT

Brown, T.G., L. Barton, and G. Langford. 1999. Coho salmon habitat within Black Creek, Vancouver Island. Can. Tech. Rep. Fish. Aquat. Sci. 2294: 75 p.

Coho salmon (*Oncorhynchus kisutch*) streams on the east coast of Vancouver Island have been subjected to changes associated with urban development, agriculture, and forestry practices. Current coho salmon spawning, summer rearing, and winter rearing habitats were characterized and coho utilization of sub-basins within the Black Creek watershed were measured. This paper describes the current status of coho salmon habitat and contrasts this to conditions documented 20 years earlier.

Although coho escapement has declined over the last 20 years, the same four locations still accounted for 90% of the spawning. The relative spawning distribution had changed slightly and coho spawning activity was absent or greatly reduced at specific sites. The swamps associated with the main channel of Black Creek accounted for two-thirds of coho rearing during summer. The upper half of the watershed supported 71% of the summer rearing. A lack of suitable water was viewed as limiting summer rearing in the lower watershed. The upper half of the watershed produced 25% of the smolts. Thus, considerable downstream movement of juveniles must occur in autumn.

We examined the utility of using a geographic information system (GIS) which uses Terrain Resource Information Management (TRIM) data as a basis for coho habitat delineation within the Black Creek watershed. The use of TRIM data without augmentation would exclude 12% of the stream length considered coho habitat and 20% of the length considered to be cutthroat trout (*Oncorhynchus clarki*) habitat. Augmentation of the TRIM data (i.e. Comox-Strathcona Sensitive Habitat Atlas) would exclude 6% of the stream length considered coho habitat and 12% of the cutthroat trout habitat.

RÉSUMÉ

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Les cours d'eau à saumon coho (*Oncorhynchus kisutch*), sur la côte est de l'île de Vancouver, ont été victimes des changements causés par le développement urbain, l'agriculture et les pratiques forestières. Les habitats actuels de fraye, de grossissement d'été et de grossissement d'hiver du saumon coho ont été caractérisés. L'utilisation par le coho des sous-bassins du bassin hydrographique du crique Black a été mesurée. La présente publication décrit la situation actuelle de l'habitat du saumon coho et la compare avec celle d'il y a 20 ans.

Malgré la diminution des échappées de coho depuis 20 ans, les quatre mêmes sites constituent toujours 90 % de la frayère. La distribution relative de la fraye a légèrement

changé, et l'activité de fraye du coho était nulle ou avait grandement diminué à des endroits spécifiques. Les marais associés au chenal principal du crique Black formaient les deux tiers de l'habitat de grossissement d'été du coho. La moitié supérieure du bassin hydrographique abritait 71 % du grossissement estival, et il semble que le manque d'eau adéquate ait limité le grossissement dans le bassin inférieur; 25 % des saumoneaux provenaient de la moitié supérieure du bassin hydrographique, et il est probable que la dévalaison des juvéniles était importante en automne.

Nous avons étudié le rendement d'un Système d'information géographique (SIG) qui utilise la banque de données « Terrain Resource Information Management » (TRIM) pour établir le profil de l'habitat du coho dans le bassin hydrographique du crique Black. L'utlisation des données TRIM, sans enrichissement, omet 12 % de longueur de cours d'eau considérés comme habitat du coho et 20 % de l'habitat potentiel de la truite fardée (*Oncorhynchus clarki*). L'enrichissement des données TRIM (par exemple, à l'aide de l'atlas des habitats vulnérables de Comox-Strathcona) n'omettrait que 6 % de longueur de cours d'eau considérés comme habitat du coho et 12 % de l'habitat potentiel de la truite fardée.

INTRODUCTION

East coast Vancouver Island streams present an excellent opportunity to examine the relationships between land use patterns and fish habitat. All coho salmon (*Oncorhynchus kisutch*) streams located on the east coast of Vancouver Island including Black Creek have been subjected to increasing pressures from encroaching urban development, agriculture, and forestry practices (Brown et al. 1996). Black Creek has historically supported a large wild coho salmon stock (maximum estimate of 15,000; Serbic 1991), however recent escapements were less than 10% of historic escapements (Figure 1). It is essential to have some knowledge of the current quantity, quality, and distribution of existing coho salmon habitat. It is also necessary to have some measure of the loss of habitat and its relevance to coho productivity. Without a detailed examination of coho habitat, we will be unable to manage it and will continue to lose this valuable resource. In this paper we delineated the current status of coho spawning, summer rearing, and winter rearing habitat within the Black Creek watershed. We contrasted current habitat conditions to those recorded by Hamilton (1978) and described juvenile coho utilization of various sub-basins. We also examined the utility of using a geographic information system (GIS) which uses Terrain Resource Information Management (TRIM) data.

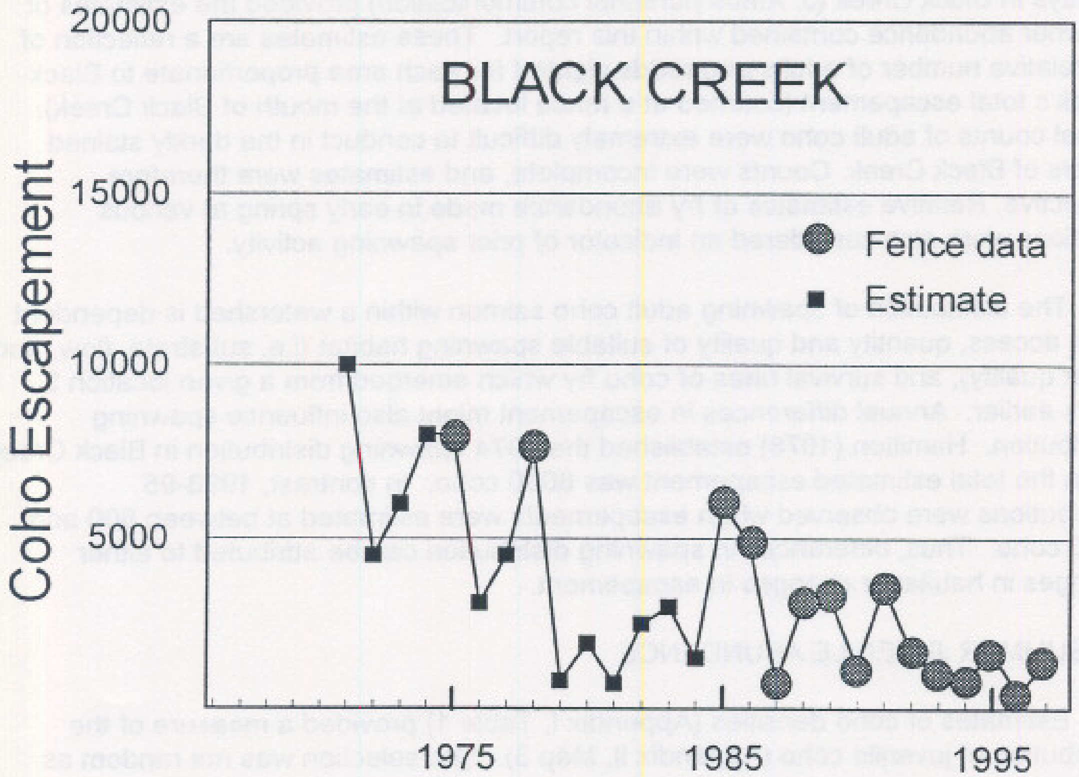

Figure 1. Escapement of coho salmon to Black Creek, 1971-1997.

STUDY AREA

Black Creek is a mid-sized stream located on the east coast of Vancouver Island between the towns of Courtenay and Campbell River (Appendix II, Map 1). The creek is 31 km long and the watershed has an area of 81 km^2 (Brown et al. 1996). Descriptions of the watershed's hydrology, climate, geology, history, spawning coho distribution, and delineation of sub-basins were provided by Hamilton (1978). A general description of the watershed, a measure of current land-use patterns, and an analysis of changes in watershed features (wetland area, length of ditches, area in crops) can be found in Brown et al. (1996). The status and trends of coho salmon escapement and smolt production from Black Creek were summarized by Kadowaki et al. (1995).

METHODS

1. SPAWNING DISTRIBUTION

Considerable caution must be used when comparing the current distribution of spawning coho (Appendix II, Map 2) with that reported by Hamilton (1978) for the year 1974 (Appendix II, Map 3). Technicians who have annually conducted spawning surveys in Black Creek (J. Amos personal communication) provided the estimates of spawner abundance contained within this report. These estimates are a reflection of the relative number of adults and redds sighted for each area proportionate to Black Creek's total escapement (counted at a fence located at the mouth of Black Creek). Visual counts of adult coho were extremely difficult to conduct in the darkly stained waters of Black Creek. Counts were incomplete, and estimates were therefore subjective. Relative estimates of fry abundance made in early spring at various locations were also considered an indicator of prior spawning activity.

The distribution of spawning adult coho salmon within a watershed is dependent upon access, quantity and quality of suitable spawning habitat (i.e. substrate, flow, and water quality), and survival rates of coho fry which emerged from a given location 3 years earlier. Annual differences in escapement might also influence spawning distribution. Hamilton (1978) established the 1974 spawning distribution in Black Creek when the total estimated escapement was 8000 coho. In contrast, 1993-95 distributions were observed when escapements were estimated at between 800 and 1200 coho. Thus, differences in spawning distribution can be attributed to either changes in habitat or changes in escapement.

2. SUMMER JUVENILE ABUNDANCE

Estimates of coho densities (Appendix I, Table 1) provided a measure of the distribution of juvenile coho (Appendix II, Map 3). Site selection was not random as sites were chosen to be representative of the habitat within each sub-basin and an effort was made to locate at least three sites in each definable drainage. Sites were selected from that portion of the watershed known to support juvenile coho, from areas that had suitable road access, and equally from ditched and natural channels. Sites were initially defined on maps to reduce the possibility of selecting sites based on pre-conceived habitat values.

The numbers of coho salmon, cutthroat trout (*Oncorhynchus clarki*), and sticklebacks (*Gasterosteus aculeatus*) were estimated by the removal method (Zippin 1958; Platts et al. 1983) with three passes of equal effort being applied at each site. Nets were placed at the top and bottom of each of the 48 sites to isolate the fish population. Two separate capture techniques were used on each pass. Fish were first netted with a two-person pole seine (width of 3-m and 2-mm mesh) and then captured by electrofishing. Sites were not disturbed for a minimum interval of 15 minutes between passes. All coho and trout were first anaesthetized and then weights and fork-lengths were measured. All fish were released after the completion of the three passes. The physical dimensions of the site (length, area, maximum depth) and habitat characteristics (substrate, riparian vegetation, adjacent land use, visual assessment of water quality, pool/riffle ratio) were recorded at the time of fish enumeration.

Two surveys of the lower 7.6 km of mainstem (estuary to Island highway) were conducted to measure the amount of summer rearing habitat available to juvenile coho. The first survey (August 17/94) was conducted during a dry summer. The second survey (August 15-18/95) was conducted during a wet summer. Comparison of the two years provides a range in wetted surface area and volume of water available for summer rearing.

Wetted channel length and width were measured using a hip chain and cloth tape. Water depth was measured with a metre stick. A rough estimate of water volume for each wetted area was obtained by multiplying the wetted area by one-half the maximum depth. During the survey water quality for each isolated pool was subjectively rated as capable of supporting fish or not based on water temperature (hand-held thermometer, < 24°C), smell, and degree of surface covered by floating vegetation. When fish were present they could be seen in small shallow pools or were captured by pole-seine in deeper more turbid waters. Isolated pools were characterized as non-habitat when both water quality was poor and fish presence was not verified.

3. WINTER JUVENILE DISTRIBUTION

Minnow trapping of juvenile fish (Brown 1985) was conducted throughout the Black Creek watershed during the winters of 1992-95 to establish the maximum distribution of coho winter rearing habitat (Appendix II, Map 4). Each minnow trap was baited with a spoonful of canned sardines in oil, contained in a perforated plastic sandwich bag, and left for 24 hr to attract fish. Traps were placed with openings parallel to the direction of any apparent flow, and a water depth of 8 cm was required before openings were accessible. A series of 20 traps was set at each site. If juvenile coho were caught at a trapping site, another trapping was conducted at a more upstream site.

Catch/trap is probably indicative of the relative fish abundance at each site, but it is difficult to equate catch/trap to densities. In one winter minnow trapping study (Brown 1985), a concentration of traps caught between one-quarter and one-third of the juvenile coho population residing at the site. We used a conservative value of one-quarter to calculate the densities given in Appendix I, Table 2.

4. DOWNSTREAM FRY AND SMOLT TRAPPING

The number of coho smolts produced from a drainage was considered to be an index of its use as winter habitat, and the capture of coho fry in spring was considered to be an indication of successful upstream spawning activity the previous autumn. The smolt and fry from four drainages in 1995, six drainages in 1996, and seven drainages in 1997 were estimated by downstream trapping. The trapping locations are illustrated in Appendix II, Map 7. Daily counts of coho fry and smolts moving downstream from April to July were obtained from fyke nets (1/4-inch stretched mesh, 2 x 3 m) with attached live boxes. All fish were anaesthetized, weighed, measured (fork-lengths), and examined for external parasites prior to their release.

In 1995 and 1996, an estimate of total daily coho smolt emigration past each fyke trap was calculated from the numbers of smolts counted relative to the proportion of wetted channel width sampled. In 1997, an estimate of the catch efficiency of each fyke net for the full downstream trapping period was calculated through mark-recapture (Appendix I, Table 3). A portion of the emigrants captured in the fyke nets were marked by cold branding (Brown 1985) and these marked fish were released upstream of the fyke nets and counted upon recapture. The ratio of recaptured marked fish to total number marked gave an estimate of each fyke trap's efficiency. Downstream smolt data will be given in detail in a later publication.

5. EVALUATION OF HABITAT MAPPING

Juvenile coho are at their maximum distribution during the winter (Brown 1987) when they occupy seasonally flooded lands and ephemeral channels. Three habitat map units (an interpretative classification) were developed with the specific purpose of aiding watershed managers in identifying coho habitats within the Black Creek watershed. The presence or absence of coho juveniles captured in winter by minnow traps, established the maximum distribution of "known" coho habitat. We considered all habitat similar in character to known coho habitat, upstream of known habitat, and into which movement of juvenile coho was not restricted to be "probable" habitat. Sections of stream were considered to be "potential" habitat if they lacked coho salmon due to a possible physical limitation in upstream movement, if they contained cutthroat trout, and if they were of a similar nature to known coho habitat. The coho habitat map units (known, probable, and potential) were outlined on base maps of the Black Creek watershed (Barton et al. 1996a, 1996b).

Fisheries and Oceans Canada is using TRIM data to spatially represent the location of known fish habitats. By overlaying the locations of coho habitat identified in this study on the TRIM base planimetric data, we were able to measure the amount of habitat (known and probable) and potential coho habitat which would be delineated on habitat maps developed solely from TRIM data.

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A GIS application to spatially represent fish habitat was developed through a cooperative project (Fisheries and Oceans Canada, Province of British Columbia, and Regional District of Comox Strathcona). This system is based on TRIM, but considerable augmentation with 1/15,000 aerial photos has the potential to add considerable information to the data base. We refer to this system as "augmented TRIM" and the resultant maps were published as the Comox-Strathcona Sensitive Habitat Atlas (1995). These maps delineated known coho and trout habitat. By overlaying the locations of coho habitat identified in this study on the augmented TRIM maps, we were able to evaluate the ability of augmented TRIM to delineate coho habitat.

RESULTS

1. COHO HABITAT BY SUB-BASIN

Hamilton (1978) divided the Black Creek watershed into 14 sub-basins. In describing the current coho habitat values associated with spawning, summer rearing, and winter rearing we utilized a similar division of the watershed (Appendix II, Map 1). Each of the sub-basins is illustrated separately within Appendix III, Maps 1-14. Measurements for each sub-basin given in Table 1 were obtained from a geographic information system (GIS) application created specifically for the Black Creek watershed (Barton et al. 1996a).

Table 1. Sub-basins of the Black Creek watershed, channel length, percentage of sub-basin channel length as ditch, area of the sub-basin, and percentage of the sub-basin area as wetland.

Basin	Location	Length (km)	Percent ditch	Area (km^2)	Percent wetland
1	Below Hwy.	20.01	28.2	7.78	2.6
2	Hamm Rd.	9.23	76.5	2.78	7.2
3	Surgenor Rd.	21.30	70.4	12.70	6.9
4	Ployart Rd.	27.26	85.5	8.82	4.2
5	Northy Lake	14.01	62.1	3.98	7.3
6	Sayer Ck.	25.97	76.8	7.67	16.3
7	Y Ditch	4.41	94.1	1.48	5.4
8	Miller Ck.	40.98	2.0	11.79	10.9
9	Ketty Ck.	4.64	25.6	1.64	7.3
10	Above Northy	12.93	31.5	5.35	24.5
11	R.O.W.	7.63	0.0	3.03	5.3
12	Powerline	9.89	0.0	5.29	5.5
13	Duncan Bay	9.00	0.0	6.18	1.6
14	Top End	7.07	0.0	3.07	5.5
Total		214.33		81.56	

Sub-basin 1

The main channel of Black Creek from the Island Highway to the Strait of Georgia has a length of 7.6 km (Appendix III, Map 1). Black Creek lacks an appreciable estuary as it enters directly into the ocean across a gravel beach. A tidal slough parallels the beach and, prior to it being channelized and culverted, this slough may have acted as an estuary. We included within sub-basin 1 a small fish-bearing drainage, which flows into this tidal slough. Hamilton (1978) did not consider this drainage part of the Black Creek watershed. A second drainage ("Lalum Road Tributary") enters Black Creek approximately 1.5 km upstream.

Black Creek main channel flows through a mix of farmland, residential properties, commercial forest, and parkland. The main channel of Black Creek for approximately 3.8 km downstream of the Island Highway Bridge parallels the Island Highway. This section of creek is low gradient (0.2%; Hamilton 1976) and farmlands and residential properties border the creek. The riparian zone of the lowest 3.8 km of Black Creek consists of a mix of conifers and hardwoods. This section has an average gradient of 1.6%, and sand and gravel accumulations suitable for spawning salmonids are common.

It is likely lower Black Creek was heavily impacted during early logging activities. During our surveys we noted accumulations of course substrate and a lack of large woody substrate. The trees in the riparian zone were 60 to 80 years old and minimal large woody debris has been added to the stream since it was logged in the 1920's. The main channel lacks structure (very few deep pools) and substrate materials were mobilized following logging activities. During a dry summer much of the water would be sub-surface, flowing through these course accumulations of porous substrate, and would be unavailable for rearing fish.

Hamilton (1978) estimated that 2400 coho spawned in the lower sub-basin in 1974. In contrast, we estimated 150 adult coho spawned in this same sub-basin in 1994. Relative to the total escapement in Black Creek, the proportion of escapement using sub-basin 1 has declined from 30% in 1974 to 15% in 1994. Spawning gravel appears plentiful within the main channel of lower Black Creek, however, the quantity and quality of water available for summer rearing during a dry summer is extremely limited (Table 2). The progeny of spawning coho using lower Black Creek would probably perish during a dry summer. Thus, this reduction in coho spawning activity may be attributed to poor summer survival of juvenile coho and not to a lack of suitable spawning habitat.

The amount of summer coho habitat within the lower main channel of Black Creek (7.6 km) was measured in August, 1994, (dry summer) and August, 1995 (wet summer). A reduction in three physical measures of fish habitat: wetted channel length (51% of total section length), wetted area (28% of 1995 area), and water volume (39% of 1995 volume) were measured (Table 2). These two surveys depict extremes in the amount of available summer rearing habitat when water quality is also considered. In a dry year, rearing area was 81% less and rearing volume was 87% less.

Lalum Road tributary (joins Black Creek approximately 1.5 km above its mouth) was classified as poor spawning habitat in 1974 (Hamilton 1978). Numerous pockets of suitable spawning material were noted within the first kilometre upstream of its confluence with Black Creek during our current surveys. We considered this tributary to have good spawning habitat in its lowest 300 metres. It is assumed that coho spawned successfully within this tributary in autumn 1994 and 1995 given that coho fry were numerous during August 1995, and smolts and emigrating fry were captured from this tributary in May, 1996. Improvement in spawning habitat may be due to recruitment of new gravel during the last 20 years. The swamps within this small tributary contained cutthroat trout (Appendix I, Table 2).

Table 2. Physical measurements of Black Creek's main channel from highway bridge to estuary during 1994 and 1995.

Measurement	August 1994 Dry summer	August 1995 Wet summer
Total length (m)	7,600	7,600
Wetted length (m)	3,900	7,600
Stagnant length (m)	600	0
Used length (m)	3,300	7,600
Wetted area (m^2)	8,300	29,000
Pool/riffle ratio	90%	73%
Pool area (m^2)	7,450	21,600
Riffle area (m^2)	850	7,900
Stagnant area (m^2)	3,350	0
Used area (m^2)	4,100	21,600
Water volume (m^3)	1,580	4,100
Stagnant volume (m^3)	1,050	0
Used volume (m^3)	530	4,100

<u>Sub-basin 2</u>

This is a small sub-basin (2.8 km^2) of which 32% of the land area is now used for agriculture (Barton et al. 1996a). Ditches currently represent 77% of the 9.2 km of channel within this sub-basin (Table 1). Approximately 1 km of non-ditched stream exists below the Island Highway (Appendix III, Map 2). This section has a gradient of 1-3% but lacks gravel substrate. Above the Island Highway, the terrain is flat and a few wetlands still remain.

This tributary was not examined for spawning coho during the current study. Spawning did occur in 1974 directly upstream of this tributary's confluence with the main channel of Black Creek (Hamilton 1978). Suitable spawning habitat is no longer present at this location and it is doubtful if this tributary could support any spawning.

Juvenile coho were captured in winter 1994-95 at Hamm Road upstream of the Island Highway. This indicates winter rearing of coho juveniles does take place within this sub-basin. However, much of the tributary is dry in summer and water quality within the few remaining pools is very poor. It is doubtful if any summer rearing habitat is available. We suspect the coho juveniles captured in winter 1994-95 (Appendix I, Table 2) had emigrated from the main channel of Black Creek into this tributary during autumn 1994.

Sub-basin 3

Sub-basin 3 is the largest sub-basin in the Black Creek watershed (12.7 km^2; Table 1). Seventy percent of sub-basin 3 has been ditched (Brown et al. 1996) and these ditches are dry in summer. The terrain is very flat and the water course divides into two channels at approximately 1 km upstream from Black Creek (Appendix III, Map 3). Hamilton (1978) speculated that the eastern half of the sub-basin (near William's Beach Road) was inaccessible to anadromous fish. This portion of the sub-basin contains three large wetlands and considerable open water (90,000 m^2). The water course within the western half of the sub-basin has been influenced by land clearing and ditching for almost all of its length.

Within the accessible portion of the sub-basin a man-made pond now exists which is capable of supporting coho in the summer. This pond, which was dug after 1976, is located 500 m upstream of the main channel of Black Creek. It is approximately 40 m long, 3 m wide, and 2 m deep. Residents described the pond as being spring fed with a stable water level and cool water temperatures throughout the summer.

Spawning coho were observed directly downstream of the Island Highway during autumn 1974. Residents bordering the tributary reported that prior to 1985 their dogs had always found coho carcasses. Although spawning coho and coho carcasses have not been observed since, in spring 1995 and 1996 a few downstream migrating coho fry were captured in a fyke net located 300 m above this tributary's confluence with Black Creek. This indicates that coho successfully spawned in autumn 1994 and 1995.

A small segment of unaltered channel directly above the Island Highway was examined in August, 1994, and five or six small isolated pools of water were found. Juvenile cutthroat trout were observed in these pools, but no coho were noted. Juvenile coho were minnow-trapped at this same location in summer 1974. A narrow riparian zone was retained along this small stream segment following the clearing of the surrounding lands in 1995-96.

Coho juveniles do overwinter within sub-basin 3. A total of 95 coho smolts was captured in a downstream fyke trap in spring 1996 (Appendix I, Table 3). These smolts were heavily infected with Neascus sp., a parasite (fluke) which leaves a conspicuous "black spot" on the fish's skin indicating the presence of a metacercaria (Northcote 1957; Schmidt and Roberts 1989). The host of this parasite, prior to its attack on fish, is a snail of the genus Helisoma (Schmidt and Roberts 1989). We observed an abundance of snails in the warmer, mud-bottomed ditches of Black Creek's lower tributaries. Thus, we suspect the coho spent both the summer and winter within this drainage.

Fyke nets captured cutthroat trout during the 2 years of spring downstream trapping. Thirteen trout were captured in 1995 and these fish ranged in length from 129 mm to 241 mm. Ninety-eight cutthroat trout were captured in 1996 and these fish ranged in length from 95 mm to 216 mm. A large cutthroat trout (500 mm) was also captured in 1996 and this was likely a sea-run cutthroat trout. No trout fry were observed in the fyke traps. We suspect these trout originated from the ponds located in the eastern half of the sub-basin. These are the only sites within the sub-basin which contain adequate water in summer to support so many large cutthroat trout.

Sub-basin 4

Sub-basin 4 is the third largest sub-basin within the Black Creek watershed (Table 1). The terrain is very flat and 41% of the sub-basin was cropland (primarily forage crops associated with dairy farming). We measured 27.3 km of channel draining this basin of which 23.3 km (86%) is ditch (Barton et al. 1996a). The majority of undisturbed channel (3 km) flows through a swamp congruous with the main channel of Black Creek. Even this section of channel may have been disturbed in the 1930's. However, historic channelization was difficult to verify.

Spawning coho have not been observed in this tributary since 1968 (Hamilton 1978). However, emigrating fry were captured in spring 1995 at the bottom of this drainage. This suggests a few spawning coho had spawned in this tributary. Only one spawning location is currently available (Appendix II, Map 5) as both the ditches and lower 3 km of drainage had mud bottoms. This small section of creek was shaded, contained gravel pockets, had a flow of water, and coho fry were noted here during June, 1998.

In August, 1994, this drainage was surveyed for salmonid summer rearing habitat. The lower portion of the drainage contained a few isolated pockets of water. Water quality within these few isolated pools was viewed as poor as water temperatures were warm (above 20^0C) and the water surface was covered with aquatic vegetation (unusable for salmonid rearing). One large pool of water (approximately 80 m^2) located 250 m upstream of the Black Creek confluence, was repeatedly pole-seined. No coho or trout were found, only sticklebacks. This same stream segment had been pole-seined in summer 1975 and hundreds of juvenile coho were captured.

This sub-basin has been extensively ditched and most of the ditches within the drainage were dry in August, 1994. Only a couple of short channel sections located within this drainage are still bordered by riparian vegetation and have the potential of supporting salmonids in summer. It is doubtful that this sub-basin can now support more than a few hundred juveniles during a dry summer.

Sub-basin 4 must be viewed as an important winter rearing tributary. In spring of 1996, a fyke net captured 577 smolts, and when trap efficiency is considered, an estimated 1443 smolts were produced from this drainage (Appendix I, Table 3). A total of 15,000 coho smolts were counted at the main Black Creek fence (Nelson and Simpson 1996). Thus, 10.2% of the smolts produced by the entire Black Creek watershed over-wintered in sub-basin 4 in 1995-96. We suspect the majority of these coho smolts emigrated as juveniles from the main channel of Black Creek (sub-basin 5 and upstream) the previous autumn.

Sub-basin 5

Habitat values for spawning, summer rearing, and winter rearing vary widely within this sub-basin. Sub-basin 5 can be divided into three sections (Appendix III, Map 5): a) Northy Lake, b) Sturgess Weir to Northy Lake, and c) Sturgess Weir to the Island Highway. Each of these sections has fisheries habitat values associated with it.

a) Northy Lake

Northy Lake is a small shallow lake (approximately 7 m max. depth, 1,500 m perimeter, and 90,000 m^2 in area) surrounded by farmland. The lake outlet has been lowered a number of times since the 1940's, and numerous ditches have been dug to improve drainage and reduce the flooding of farmlands. The lake and associated wetlands were more extensive prior to land development. At present a riparian border of willow and brush extends around the lake's perimeter.

The lake does not support spawning coho and the summer and winter rearing potential of Northy Lake for coho salmon is largely unknown. Numerous cutthroat trout are present within the lake. They were observed swirling at the lake surface, have been caught by anglers, and were captured at the lake margins by Taccogna (1996). Minnow trapping during March, 1997, failed to capture any coho (Appendix I, Table 2, MST13425). Minnow traps did not capture coho in summer, and attempts to capture summer rearing coho along the margins of the lake with an electroshocker were not successful (Taccogna 1996). However, ditches adjacent to the lake had coho rearing within them during winter (Appendix I, Table 2, MST14625 and DIT200).

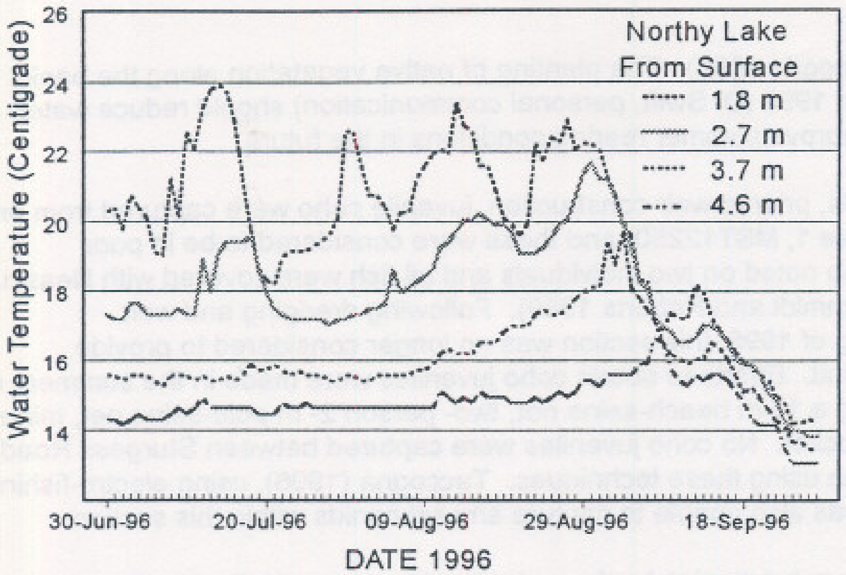

Figure 2. Northy Lake water temperatures taken at four depths.

The surface waters and lake margins could have supported rearing coho salmon and cutthroat trout in the summer. Lake surface temperatures were tolerable in summer 1996 (Figure 3) and surface mixing occurred to approximately 3 m. Waters deeper than 3 m had a low dissolved oxygen content in summer (88% at 2 m depth and 27% at 4 m; Taccogna 1996). Fixed ropes hauled from depths greater than 3 m lacked epiphytic growth and were covered with a black slime. No fish were captured in minnow traps placed in deeper waters (Taccogna 1996). Coho have been documented to use small lakes on the east coast of Vancouver Island similar to Northy Lake (Fielden and Holtby 1987; Irvine and Johnston 1992). We suspect Northy Lake contains both summer and winter rearing coho.

b) <u>Northy Lake to Sturgess Road</u>

Black Creek from Northy Lake to Sturgess Road was heavily impacted in the 1950's when the main channel was channelized by bulldozer (Hamilton 1978). The main channel upstream of Sturgess Road was considered marginal to poor spawning habitat in 1974 (Hamilton 1978). This section has since been re-channelized (1.25 km in autumn 1994), eliminating the few remaining gravel pockets which coho would have used for spawning. A log weir was constructed directly upstream of the Sturgess Road Bridge in 1994.

This section of the main channel of Black Creek upstream of Sturgess Road now lacks riparian vegetation, has no channel complexity, and contains water of a quality unsuitable for summer rearing fish. Summer water temperatures were intolerable (27.5 °C; at Sturgess Road, July, 1994) and dissolved oxygen levels deteriorated from a surface O_2 saturation level of 98% at the Northy Lake outlet to 60% just upstream of

Sturgess Road (Taccogna 1996). The planting of native vegetation along the banks of this stream section in 1996 (D. Swift, personal communication) should reduce water temperatures and improve summer rearing conditions in the future.

In October, 1994, prior to weir construction, juvenile coho were captured from one site (Appendix I, Table 1, MST12250) and these were considered to be in poor condition. Fin rot was noted on two individuals and all fish were covered with Neascus sp. metacercaria (Schmidt and Roberts 1989). Following dredging and weir construction in spring of 1995, this section was no longer considered to provide summer rearing habitat. Efforts to obtain coho juveniles were made in the summers of 1995 and 1996 using a 15-m beach-seine net, two- person 2- m pole-seine net, minnow traps, and electroshocker. No coho juveniles were captured between Sturgess Road Weir and Northy Lake using these techniques. Taccogna (1996), using electro-fishing and minnow traps, was also unable to capture any salmonids within this section.

Once the heavy autumn rains begin, water temperature and dissolved oxygen problems are no longer a concern and this sub-basin has the potential of providing excellent winter rearing habitat. The lack of channel complexity and cover reduces the capacity of the section between Sturgess Road and Northy Lake to provide winter rearing for coho salmon. However, coho growth rates may be higher in spring within the slightly warmer (increased solar radiation) and nutrient enriched-waters (from bordering farmlands). Numerous cross-ditches enter Black Creek below Northy Lake and we suspect these ditches also provided good winter habitat.

c) <u>Sturgess Weir to Island Highway</u>

The stream from Sturgess Road to the Island Highway Bridge (3.5 km) is bordered by thick riparian vegetation and flows through the last two remaining main channel wetlands downstream of Northy Lake. The watercourse through these swamps is diffuse and hard to follow, yet deep pockets of water (greater than 2 m) exist upstream of beaver dams. Since channelization 40 years ago, the condition of spawning and rearing habitat has improved. However, the wetlands are within the Agricultural Land Reserve and future development could jeopardize some of the best spawning and rearing habitat in the watershed. Summer water discharge and quality are a concern due to upstream activities.

The section of Black Creek directly downstream of Sturgess Road is one of the four best spawning locations within the Black Creek watershed. Hamilton (1978) estimated that 1000 coho (13% of 1974 escapement) spawned in the mainstream between Northy Lake and the Island highway. The greatest proportion of this spawning occurred within the first 1.5 km below the Sturgess Bridge. In 1994, we estimated 200 adult coho (or 20% of 1994 escapement) utilized this sub-basin. Although there has been a decline in coho escapement, there has been a slight increase in the relative proportion of Black Creek's coho escapement now utilizing sub-basin 5 (Figure 2).

In 1996, a spawning/winter rearing channel was constructed parallel and adjacent to a section of creek, approximately 500 m downstream of Sturgess Road. Spawning coho were noted in this channel in autumn of 1997 and 1998.

Summer and winter rearing conditions were excellent within the wetlands downstream of Sturgess Road. A high number of coho juveniles (1.35 coho/m) were obtained here in summer 1994 (Appendix I, Table 1, MST11325 and MST11775). Juvenile coho were captured here in winter 1994 (Appendix I, Table 2, MST11775).

Sub-basin 6 (Sayer Creek)

Twenty-six km of channel drained this sub-basin. Seventy-seven percent of the 26-km channel consisted of ditches and cross-ditches (Table 1). The majority of the main channel (75%) had been ditched (Appendix III, Map 6). The last remaining unditched main channel segment (lower 1.5 km) was logged in 1975 and the riparian zone is now vegetated with alder and bush. A small pond (Cranberry Lake, 40,000 m^2) held water through the summer. The upper 1.5 km of main channel bordered a potato farm and these fields were flooded in winter.

In the 1930's and 1940's this sub-basin was heavily used by spawning coho, and reports of local farmers removing wheelbarrows full of salmon carcasses to fertilize their fields were noted by Hamilton (1978). In 1974, a dozen spawning coho were recorded upstream of the Kelland Road Bridge (Appendix II, Map 7). Six spawning coho were noted by a resident upstream of Cranberry Lake in 1985.

We suspect current spawning activity upstream of Kelland Road is limited to one small section of channel downstream of Cranberry Lake (Appendix I, Map 5), which contained a few pockets of gravel. In 1995, 1996, and 1997, coho fry were caught at the Kelland Road Bridge in a fyke net. Thus, coho spawning did occur during all of the previous autumns.

In summer 1996, spawning gravel was added to a small drainage entering Sayer Creek approximately 1 km upstream of Kelland Road (D. Swift, personal communication). In the spring of 1997, coho fry were captured in a fyke net situated directly downstream of this gravel placement. This indicates that coho successfully spawned in this drainage in the autumn of 1996.

The section of stream downstream of Kelland Road did contain pockets of gravel, and should support spawning coho. We did not walk this lower section of channel and count spawning coho during our study. Thus, we can not compare spawning numbers to those reported by Hamilton (1978).

Summer rearing habitat is available downstream of Kelland Road. In 1994, coho densities of 1.9, 1.4, and 0.0 coho/m of stream were measured (Appendix I, Table 1). The fish were trapped in isolated pools of water and appeared to be under considerable stress (small size, slender, and some deformities noted). Summer rearing habitat downstream of Kelland Road is limited by low summer flow. Rearing habitat is available in a wet summer, while in a dry summer few fry will survive.

Summer rearing habitat upstream of Kelland Road was limited to Cranberry Lake and a few small ponds created by beavers downstream of Cranberry Lake. The majority of the main channel upstream of Kelland Road has been ditched and goes dry in the summer. Cranberry Lake could support rearing coho, but the extent of coho rearing within the lake has not been examined.

Winter rearing habitat within sub-basin 6 was considered excellent. We suspect coho which had summer-reared elsewhere, perhaps in the swamps of sub-basin 5 and 10, moved into this tributary during the autumn. Minnow traps placed upstream of Kelland Road caught large numbers of coho juveniles in winter (Appendix I, Table 2). These same sections were dry or inhospitable to coho during the previous summer. Coho winter rearing distribution was extensive as coho juveniles were captured at the top end of this drainage in the ditches surrounding the potato fields.

A fyke net located at the Kelland Road Bridge was operated for 3 years (Appendix I, Table 3). However, the trap was installed late in 1995 and only captured a small portion of the emigrating smolts. We estimated that between 7 to 10% (1996-97) of Black Creek's smolt production over-wintered upstream of Kelland Road in sub-basin 6.

Sub-basin 7

This is the smallest sub-basin within the Black Creek watershed (1.5 km^2, Table 1). Hamilton (1978) defined it as a separate sub-basin even though it could have been considered a part of sub-basin 5. This sub-basin has been almost totally ditched (90%, Table 1) and two separate ditching networks were evident (Appendix III, Map 7). The first ditch network drains northeast and joins Black Creek 600 m downstream of Sturgess Road. The second network drains northwest towards Northy Lake where it joins with other ditches considered to be part of sub-basin 5. The ditches drain surrounding pastureland. No trees exist along any of the ditches, and no discernible flow was evident from the ditches during low summer flow.

The bottom of the ditches consisted of clay and mud and no suitable spawning substrate was evident. The ditches contained standing water in summer but without aeration, the water quality was poor. The lowest 200 m of the first ditch network was viewed as the best summer habitat and did contain both summer rearing coho and cutthroat trout (Appendix I, Table 1). Juvenile coho salvage operations conducted September 29-30, 1996 (memo K. Urchuk to D. Swift, Sept. 1996) removed 159 coho after minnow trapping and electro-shocking (2 passes) the entire accessible portion of sub-basin 7. This ditch system does provide suitable winter rearing habitat and emigrating coho smolts were captured in the spring of 1995 in a fyke net located 50 m above Black Creek (Appendix II Map 7).

Sub-basin 8 (Miller Creek)

Miller Creek shares an 11-km watershed boundary with the Tsolum River to the southwest. The flow pattern of minor drainages and swamps and delineation of watershed boundaries between the Tsolum River and Miller Creek was at times questionable. The terrain is very flat and swampy, and water courses were often diffuse and hard to follow. Differences between our interpretation of the inter-connections between water courses and those given by TRIM were evident. Our interpretation (Appendix III, Map 8) is consistent with that given by Hamilton (1978).

Miller Creek consisted of 41 km of stream (Table 1) of which only the lower 450 m borders cropland, lacks a riparian buffer, and has been channelized. Numerous beaver dams and swamps were evident throughout the watershed above this section. Land-use analysis of Miller Creek sub-basin (Barton et al. 1996a) divided the use into 1% cropland, 5% hydro right-of-way and roads, 10% recently logged land, 11% wetland, and 73% second growth timber. The standing timber within this watershed is of a uniform age. A major forest fire burned the Miller Creek basin and much of the upper Black Creek watershed in 1938. One second-growth timber block adjacent to lower Miller Creek was cut in 1996-97.

Fisheries and Oceans Canada staff has enumerated adult coho within three index reaches (each reach is 250 m long) on Miller Creek from 1987 to 1993 and in 1997 (J. Irvine, personal communication). In 1987, 38 adult coho were counted in three index reaches (Bocking et al. 1988) and in 1997, 37 adult coho were counted (Kent Simpson, personal communication). The average count from the three index sites for the 8 years is 37. While the percentage of the watershed's coho escapement that spawned in Miller Creek has increased from 10 to 15% (Figure 3), the actual number of spawning coho has declined from an estimated 800 in 1974 (Hamilton 1978) to an estimate of 150 in 1997. Although the entire sub-basin was not surveyed for spawners, we suspect most of the spawning activity in Miller Creek has been located at or below the hydro right-of-way (Appendix II, Map 5).

Fisheries and Oceans Canada staff have enumerated juvenile coho from sample sites (30-50 m long) located 100 m to 500 m upstream from the edge of the fields in lower Miller Creek during July (1992-1994) or September (1995-1997). A stream section of approximately 50 m in length yielded 230 fry in 1992, 260 fry in 1993, and 199 fry in 1994 or estimates of 4.6, 5.2, and 4.0 coho/m, respectively (J. Irvine, personal communication). Coho densities of 4.9, 1.5, and 2.7 coho/m for 1995, 1996, and 1997, respectively, were calculated (K. Simpson, personal communication). The density of summer rearing juvenile coho equates to an average of 3.8 coho fry/m for the 6 years (1992-1997) this creek section has been sampled. In October, 1994, we sampled 3 sites (Appendix I, Table 1) and these three sites averaged 3.5 coho/m.

Although we considered Miller Creek to contain some of the best winter rearing habitat in Black Creek, the smolt production from this sub-basin was below what we expected. In 1979, a downstream trap was operated on lower Miller Creek (Clark and

Irvine 1989). Between April 21st and June 1st, 1979, 3503 coho smolts were caught. This represented 7.6% of Black Creek's total smolt output in 1979. In 1997 (April 1 to July 30), we operated a fyke net in approximately the same location as did Clark and Irvine (1989). We caught 439 smolts and estimated 1877 smolts or 2.5% of Black Creek's total smolt output came from Miller Creek. Minnow traps placed in Miller Creek above the hydro right-of-way in 1993, 1994, and 1995 caught very few juveniles (Appendix I, Table 2), and a fyke trap placed on the fork nearest the hydro right-of-way captured only 64 coho smolts during spring 1996 (Appendix I, Table 3).

The channelization of the lower 450 m of Miller Creek has eliminated spawning habitat and impacted on summer and winter rearing habitat. Adult coho were observed spawning in Miller Creek directly upstream of Northy Lake during autumn 1974. The removal of riparian vegetation and channelization of the stream in 1994 has eliminated spawning gravel for a distance of approximately 450 m. No juvenile coho were captured from three sites (30 m in length) in the lower 450 m of Miller Creek during summer 1994 (Appendix I, Table 1) while in the unaltered section of stream directly upstream, an estimated 207 juvenile coho were rearing in three sites (3.5 coho/m). In summer 1994, 39 cutthroat trout were captured upstream of the fields and 18 cutthroat were captured within the lower channelized section. In the winter of 1997, we estimated 0.02 coho/m (1 coho captured) in the lower 450 m and 0.25 coho/m (21 coho captured) upstream of the fields (Appendix I, Table 2).

<u>Sub-basin 9 (Ketty Creek)</u>

In 1974-75, Hamilton (1978) observed 250 spawning coho at the outlet of the large swamp which dominates sub-basin 9 (Appendix III, Map 9). When viewed in 1974-75, the outlet stream had been channelized and the substrate was hard clay. We speculated that these spawning coho were the offspring of brood years prior to channel alteration. With the removal of suitable spawning habitat, spawning was unsuccessful and coho were eliminated from this drainage. In 1997, spawning gravel and stabilizing material were added to this ditch. In autumn 1998, 16 coho carcasses were counted in this drainage.

In the early 1980's, a 3-m high dam was constructed at the swamp outlet to store water for irrigation. This structure prevented the upstream movement of both juvenile and adult coho into the swamp. In the autumn of 1974, prior to impoundment, juvenile coho were observed in the swamp. In 1997-98 the dam at the outlet of the swamp was removed and a new structure was built. This new structure was designed to control water release and to allow adult and juvenile fish passage into the swamp. The slow release of water through the summer (estimated to be 0.3 cfs between July 1st and Sept 15 th (M. Sheng, personal communication)) should improve summer rearing habitat downstream of the dam.

Before fish passage was provided at the outlet of the swamp, the length of accessible channel available for rearing was limited to 1400 m of ditch. A dozen coho fry were noted in one pool during spring 1995 directly below the dam site. The origin of these fry is uncertain. They may have migrated upstream from the main channel of Black Creek. Winter rearing of juvenile coho did occur in 1996-97 as coho juveniles were captured in minnow traps (Appendix I, Table 2) and in a downstream fyke (Appendix I, Table 3). The number of juvenile coho over-wintering in sub-basin 9 was estimated to be less than 50 based on our catch in the fyke net.

Sub-basins 10 and 12

In sub-basins 10 and 12, the main channel of Black Creek meandered for 9.5 km through a wide network of swamps with numerous side channels and beaver ponds. This swamp system was continuous from Duncan Bay Main to Northy Lake. Spawning habitat (small pockets of gravel) were evident directly above and below the hydro right-of-way (Hamilton 1978). The remainder of the main channel is dominated by a muck substrate.

Summer and winter rearing habitats were abundant. Fry which emigrate downstream from spawning locations in lower sub-basin 13 could find a sufficient high quality water for summer rearing and complex habitats and back-channels for winter rearing. We suspect these sub-basins provided the best available summer rearing habitat in the Black Creek watershed. The swamps and beaver ponds were also important for storing and slowly releasing water to areas downstream.

Summer fry densities from Duncan Bay Main Road to Northy Lake ranged from 3.9 to 0.2 coho/m and averaged 2.1 coho/m (Appendix I, Table 2). The lowest density was measured at the lowest point in sub-basin 10 and the highest densities were measured at the top of sub-basin 12. This may indicate that the rearing potential of both sub-basin 10 and 12 is under-utilized and insufficient fry are produced from upper spawning sites to fill the rearing capacity of this swamp system.

Sub-basin 11

This tributary originated in a swamp system upstream of the hydro right-of-way and flowed downstream into sub-basin 10 (Appendix III, Map 11). It had a few gravel pockets in its lowest 600 m, which supported spawning coho. Spawning did take place in this drainage in autumn of 1995, as 200 coho fry were obtained in a fyke net located at the bottom of this tributary during spring 1996 (Appendix II, Map 7). Adult cutthroat trout and cutthroat trout fry were also obtained in the fyke net. The few pockets of spawning gravel are a valuable component of this tributary. Emerging coho fry would find abundant rearing habitat by either moving upstream across the hydro right-of-way into the swamp system or by moving downstream into sub-basin 10.

Two isolated pockets of water were present downstream of the hydro right-of-way and 4 coho juveniles were captured here by an electro-fisher in the summer of 1994. The swamp upstream of the hydro right-of-way does support both summer and winter rearing. Juvenile coho were captured within this swamp during summer and winter

(Appendix I, Tables 1 and 2). In spring 1996, 79 smolts were captured in a fyke net located at the bottom of this drainage (Appendix I, Table 3).

Sub-basins 13 and 14

Stream gradient increased noticeably at Duncan Bay Main and the hydrological conditions required to produce good quality spawning substrate were apparent. A steady flow of cool, clear water was evident at Duncan Bay logging road during late summer. The upper sub-basins of Black Creek were dominated by second growth forest (>90% of area). Blocks of second growth timber were being harvested during 1994-96.

Black Creek divides into a circular swamp network approximately 200 m upstream of the lower margin of sub-basin 14 (Appendix III, Map 14). Coho were not observed in sub-basin 14 during this study, however, minnow traps (Appendix I, Table 2) captured cutthroat trout. A waterfall, which is impassable to adult salmon, is located 250 m above the lowest swamp in sub-basin 14 (Appendix III, Map 14).

The number of coho spawning in the upper mainstem of Black Creek has declined from 2,800 in 1974 (Hamilton 1978) to an estimated 350 in 1994. The relative proportion of the watershed's total spawning activity has remained constant at 35%. Approximately 4 km of the upper watershed (300 m to 4300 m upstream of Duncan Bay Main) was used in 1974 (Appendix I, Map 6) but has not been used in recent years (Appendix I, Map 5). The upper limit of coho spawning within Black Creek (1994-96) was approximately 300 m upstream of Duncan Bay Main.

We characterized the upper 6.0 km of Black Creek as potential habitat instead of probable or known habitat (Appendix I, Map 5). Hamilton (1978) clearly delineated 4.0 km of the upper main channel as spawning habitat and no barrier to adult upstream movement was identified during this study. However, repeated sampling in both summer and winter failed to establish the presence of rearing coho within this section. We suspect there may have been a logjam located approximately 300 m upstream of Duncan Bay Main, which prevented upstream movement during the 1980's, but this was never clearly documented. No blockage now exists and coho adults are free to move to within 1.5 km of the upper end of the watershed.

Coho rearing within sub-basin 13 is limited to the lowest 750 m of channel (Appendix III, Map 13). The upper limit of summer rearing in 1994 was 500 m above Duncan Bay Main. In autumn 1994, a coho fry density of 1.9 coho/m was measured in the 250 m of channel just downstream of Duncan Bay Main (Appendix I, Table 1) while 0.1 coho/m was measured in the 500 m upstream. Also, higher densities of summer rearing coho and higher minnow trap catches of coho in winter were obtained downstream of sub-basin 13 than within it (Appendix I, Table 1 and 2). Heavy spawning occurred in sub-basin 13 (Figure 3). Thus, the majority of coho fry must have moved downstream into the 9.5 km of swamp, which comprises sub-basins 10 and 12.

2. SUMMARY OF HABITAT USE

a) Spawning Habitat

Total coho escapement to Black Creek (Figure 1), has declined from an estimated 8,000 in 1974 (Hamilton 1978) to a mean escapement of 1,470 (1990-96; Simpson et al. 1997). Four locations accounted for 90% of all coho spawning activity in 1990-96 (Figure 3). These 4 locations were similar to those delineated by Hamilton (1978) and represented approximately 88% of the coho spawning activity in 1974. These four locations are as follows:

1) main channel Duncan Bay Main (sub-basin 13);
2) main channel below Sturgess Road (sub-basin 5);
3) main channel Highway 19 to estuary (sub-basin 1);
4) Miller Creek (sub-basin 8).

Although the total percentage of escapement, which uses the four locations, has not changed since 1974, the relative contribution (Figure 3) and specific distribution within the sites has changed. Coho spawning activity is currently lacking or is reduced at specific locations where spawning activity was noted in 1974. The most notable changes since 1974 are:

1) No spawning in the upper 5 km of the watershed. This may be due to reduced escapement.
2) No spawning in sub-basin 9 (Ketty Creek). This is due to channelization as well as complete blockage of coho upstream movement.
3) Reduction in number of spawning coho using the lower main stream. We speculated that poor fry survival due to low summer flows has reduced adult returns.
4) Lower escapements to sub-basins 2-4 and 6. This is likely due to habitat loss associated with land development (ditching and clearing).

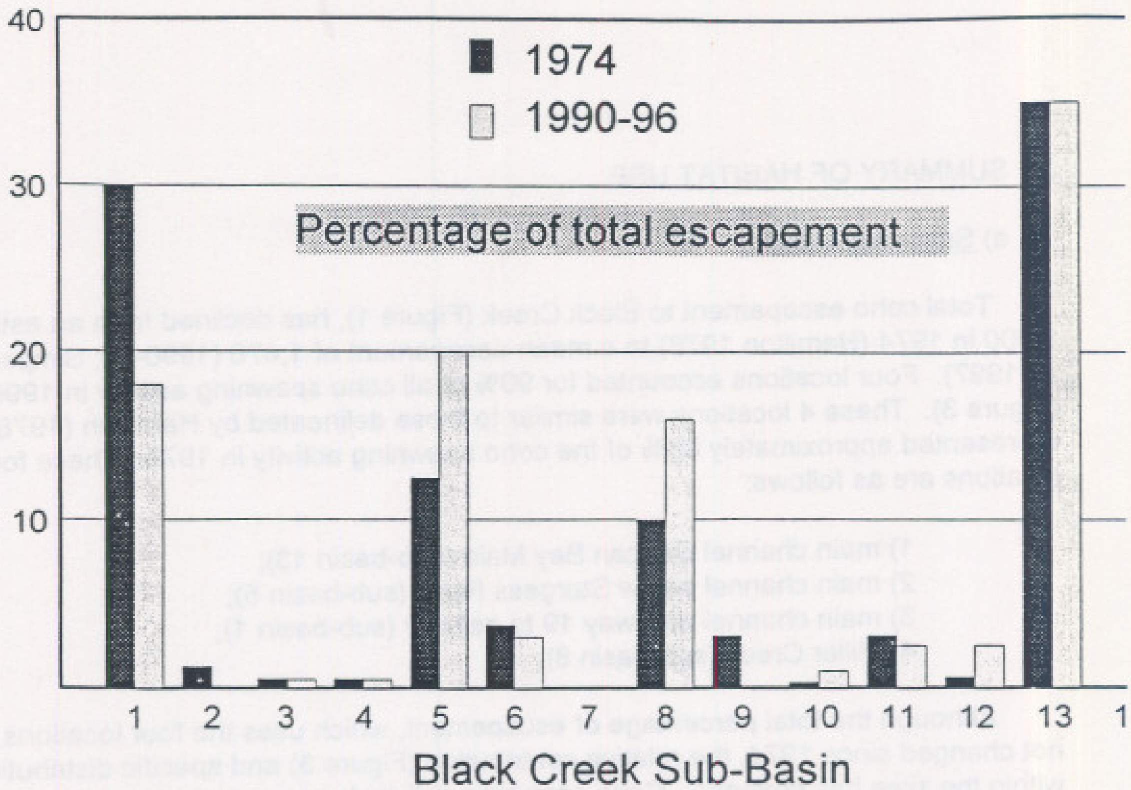

Figure 3. Relative distribution of spawning coho salmon for 1974 and 1990-96.

b) <u>Summer Habitat</u>

Coho densities were estimated during late summer of 1994, a dry summer with low brood year escapement. These summer density estimates (Appendix I, Table 1) combined with lengths of known summer habitat (Barton et al. 1996b) gave an indication of the relative importance of each sub-basin for rearing of coho in summer (Table 3).

The importance of the mainstem swamps is apparent from Table 3. Sub-basins 5, 10, and 12 contained virtually all of the remaining large accessible wetlands which border the main channel of Black Creek and contained 69% of the summer rearing juvenile coho. All of these mainstem swamps are within the agricultural land reserve (Hamilton 1978). In a dry summer (1994) the portion of the watershed above Northy Lake (including Miller Creek) supported two-thirds (71%) of Black Creek's coho juveniles (Table 3).

Summer rearing below Northy Lake accounted for less than one-third of the rearing capacity of Black Creek (Table 3). We suspect that summer rearing below Northy Lake has been limited due to a lack of water and poor water quality. Coho density estimates were obtained during a dry summer (1994). We speculated that in a wet summer more habitat would be available and more coho should be present in the autumn within the lower watershed.

Some accessible sections of excellent summer rearing habitat were not utilized by coho in 1994. These include 6 km of main channel habitat in sub-basin 13 and 14, and 9.6 km of swamp habitat in sub-basin 8 (Miller Creek). We suspect the lack of summer rearing in these areas was related either to low adult escapements to Black Creek the previous year or to a lack of available spawning habitat.

Table 3. Relative number of juvenile coho rearing in each of Black Creek's sub-basins at the end of summer 1994. Habitat length from Barton et al. (1994b).

Basin	Density (coho/m)	Length (km)	No. coho	Percent of total
1	0.47	8.1	3819	6.4
2	0.00	0.0	0	0.0
3	0.50	0.3	150	0.3
4	2.00	0.8	1600	2.7
5	1.31	7.0	9164	15.3
6	1.10	1.9	2090	3.5
7	0.19	1.1	210	0.4
8	1.73	5.5	9500	15.9
9	0.05	1.4	72	0.1
10	2.17	7.5	16303	27.3
11	0.19	2.5	485	0.8
12	2.17	7.2	15651	26.2
13	0.51	1.4	714	1.2
14	0.00	0.0	0	0.0
Totals		44.7	59756	100.0
Basins 5,10,12		21.7	41118	68.8
Below Northy		19.2	17032	28.5
Above Northy		20.0	33224	55.6
Miller		5.5	9500	15.9

The summer rearing utilization of two small lakes (Northy and Cranberry) is unknown. Despite repeated attempts to capture juvenile coho, none was obtained. We suspect coho fry reside in the lakes during summer and winter but densities were low. The lakes do support cutthroat trout and there is recreational trout fishing on Northy Lake (Doug Swift, personal communication).

c) <u>Winter Habitat</u>

A total of 78.7 km of coho winter rearing habitat is currently being used within the Black Creek watershed (Table 4). This includes 55.4 km of known habitat and 23.3 km of probable habitat. The upper limit of spawning in 1994-97 was 300 m above the Duncan Bay logging road (sub-basin 13), while in 1974 an additional 7.3 km of habitat was used. If this historically used habitat is also included, 86 km of habitat (40% of drainage) is currently available to coho. We suspect that most of the probable habitat within sub-basin 4 and 8 would be utilized following years of high coho escapement.

Cutthroat trout used all known, probable and potential habitats (Table 4). Therefore, trout used 125.7 km of stream channel (59% of the watershed). This is a minimum value as trout may reside within the upper 5.7 km of sub-basin 14, upstream of the falls, which was not surveyed during our study.

The winter catch of juvenile coho in minnow traps indicates a gregarious distribution with highly variable catches (Appendix II, Table 2). Catches at sites separated by 100 m (Appendix II, Table 2; KEL1150 vs. KEL1250) were significantly different ($P < 0.01$; Mann-Whitney Rank Sum Test). Estimates of coho winter rearing numbers calculated from habitat length multiplied by densities are unlikely to be very accurate due to this high variation and because too low of a proportion of the sub-basin's total length was enumerated. The density of cutthroat trout was positively correlated to the distance upstream (Linear Regression; $P < 0.01$) while the density of stickleback was negatively correlated with distance upstream (Linear Regression; $P < 0.01$).

A more assessment of the size of the winter rearing population of coho salmon is obtained by counting smolts migrating from the various sub-basins (Appendix II, Map 7). Estimates of trap efficiency and total coho smolt emigration are given in Appendix I, Table 3. In spring 1997, Miller Creek produced 1877 $\pm$ 490 (95% CL) coho smolts, while the watershed above Northy Lake produced 17,215 $\pm$ 1170 (95% CL) coho smolts. An estimated 76,238 smolts passed through the main downstream fence at the mouth of the Black Creek watershed during spring 1997 (Kent Simpson, personal communication). Thus, 25% $\pm$ 2% of Black Creek's 1997 smolt production originated from upstream of Northy Lake.

Coho smolt production from upstream of Northy Lake was primarily from sub-basin 10. A fyke net placed downstream of the hydro right-of-way on the main channel of Black Creek ("Upper"; Appendix I, Table 3) captured smolts produced from sub-basins 12 and 13. We estimated that in 1997, only 555 smolts (< 1%) of Black Creek's coho smolt production (winter rearing) originated from sub-basins 12 and 13.

A considerable number of summer rearing coho must have moved downstream from upper sub-basins to over-winter in lower sub-basins. The sub-basins above Northy Lake (8 to 14) accounted for 71% (Table 3) of the summer rearing but only 25%

of the smolt production (Appendix I, Table 3). The productivity of Black Creek's sub-basins will be examined in detail in a future publication.

Table 4. Length of juvenile coho winter rearing habitat within Black Creek's sub-basins based on catch by minnow traps (1994, 1995, 1996). Where "known" is defined by coho presence, "probable" is defined by similar habitat above known habitat but lacking coho, and "potential" is defined by similar habitat but inaccessible to juveniles.

1996 Maps

	Basin	Length (km)	Coho habitat features (km)			
			Known	Probable	Potential	Non-coho
1	Below Hwy.	20.0	10.0	0.2	1.6	8.2
2	Hamn Rd.	9.2	2.2	0	1.4	5.6
3	Surgenor Rd.	21.3	2.9	2.1	4.0	12.3
4	Ployart Rd.	27.3	2.1	6.9	8.0	10.3
5	Northy Lake	14.0	7.0	0.5	0	6.5
6	Sayer Ck.	26.0	5.8	2.2	2.7	15.3
7	Y Ditch	4.4	1.1	0.6	0.4	2.3
8	Miller Ck.	41.0	5.5	9.6	12.5	13.4
9	Ketty Ck.	4.6	1.4	0	2.4	0.8
10	Above Northy	12.9	7.5	0	2.2	3.2
11	R.O.W.	7.6	1.6	0.9	2.7	2.4
12	Powerline	9.9	6.9	0.3	0.4	2.3
13	Duncan Bay	9.0	1.4	0	7.3	0.3
14	Top End	7.1	0	0	1.4	5.7
Total		214.3	55.4	23.3	47.0	88.6

3. EVALUATION OF TRIM

The use of TRIM data as base maps in coho habitat delineation must be done with extreme care. A considerable percentage (48%) of the total Black Creek drainage network was absent from the TRIM maps (Brown et al. 1996). In a similar study, (Williams et al., in preparation) a comparison of a digital 1:5000 map produced by Timber West for the upper Comox Valley on Vancouver Island, with TRIM data for the same area, found 30% of the stream length delineated in the 1:5000 map was missing from the TRIM data.

The inclusion of the Black Creek drainage network missing from TRIM is essential as many of the minor tributaries and seasonal watercourses were coho habitat or flow into coho habitat. Much of the missing network supports cutthroat trout. We estimated that 10.1 km or 12% (10.1 km/86 km) of coho habitat and 15.2 km of potential coho habitat was absent from the TRIM maps (Table 5). All the potential coho habitat contained cutthroat trout. Thus, at least 25.3 km or 20% (25.3 km/125.7 km) of Black Creek's salmonid habitat was absent from the TRIM maps.

Table 5. Comparison of TRIM maps with salmonid habitat atlas (Barton et al. 1996b). "Delineated" refers to total channel length identified by TRIM, while "Non-delineated" refers to additional coho habitat and potential habitat identified within the atlas.

		TRIM		
		Delineated	Non-delineated	
Basin		Total (km)	Habitat	Potential
1	Below Hwy.	11.6	0.2	0.3
2	Hamn Rd.	1.3	0.9	1.4
3	Surgenor Rd.	10.8	0	0
4	Ployart Rd.	10.4	0.5	4.2
5	Northy Lake	8.5	1.2	0
6	Sayer Ck.	11.3	1.6	0.6
7	Y Ditch	0.8	0.9	0.4
8	Miller Cr.	24.6	0.8	3.2
9	Ketty Ck.	0.0	1.4	2.4
10	Above Northy	6.0	1.5	2.2
11	R.O.W.	3.0	0.2	0.5
12	Powerline	9.0	0.3	0
13	Duncan Bay	8.3	0.6	0
14	Top End	6.1	0	0
Total		111.7	10.1	15.2

4. EVALUATION OF AUGMENTED TRIM

Augmentation of TRIM maps with aerial photos was an improvement over the use of TRIM without the augmentation. An additional 26.9 km of channel length was added to the TRIM base to total 138.6 km (Table 6). However, the existence of 6.9 km of the added channel length was not verifiable by "ground-truthing." We calculated that 5.5 km or 6% (5.5 km/86 km) of the channel length delineated as coho habitat (Table 3) and 11.3 km as potential coho habitat by the 1996 maps (Barton et al 1996b) was absent from the augmented TRIM maps (Table 6). All the potential coho habitat contained cutthroat trout. Thus, at least 16.8 km or 13% (16.8 km/125.7 km) of the total salmonid habitat was absent from the augmented TRIM maps.

Salmonid distribution was spatially represented as known and unknown on the augmented TRIM maps (Table 6). The augmented TRIM maps characterized 49.2 km of channel as salmonid habitat and 89.4 km as unknown (Table 6). The 1996 maps (Barton et al. 1996b) characterized 78.7 km (55.4 km known + 23.3 km probable) of channel as coho habitat and 47 km as potential coho habitat (Table 4). We estimated that 40.7 km of channel was incorrectly characterized on the augmented TRIM maps. This included 34.8 km identified on the 1996 maps as habitat which was labelled as unknown on the augmented TRIM maps, and 5.9 km which was labelled as known habitat on the augmented TRIM maps, and which was characterized as potential habitat on the 1996 maps. The augmented TRIM maps correctly identified 60% of the "known" habitat, 46% of the "probable" habitat, and 32% of the potential habitat.

The ability of augmented TRIM to identify habitat is dependent upon the size of the channel. A similar length of Black Creek's main channel was delineated as habitat by the two methods, however, differences were apparent in delineation of salmonid habitat in the 14 tributaries known to contain juvenile coho. The augmented TRIM maps noted the presence of coho in three of six major tributaries (basins > 2.5 km^2) and two of eight minor tributaries (basins < 2.5 km^2).

Table 6. Comparison of Augmented TRIM with Salmonid Habitat Atlas (Barton et al 1996b). "Delineated" refers to channel lengths identified by Augmented TRIM. "Non-delineated" refers to coho habitat and potential habitat identified within the atlas (Barton et al 1996b) but not by Augmented TRIM. "Mis-classified" refers to coho habitat identified by the atlas and classified as "unknown" by augmented TRIM or channel length "added" as habitat by augmented TRIM but not considered habitat by the atlas.

	Augmented TRIM						
	Delineated			Non-delineated		Mis-classified	
Basin	Total	Known	Unknown	Habitat	Potential	Unknown	Added
1 Below Hwy.	12.5	8.6	3.9	0.2	0.3	2.9	0.7
2 Hamn Rd.	1.3	0	1.3	0.9	1.4	2.2	0
3 Surgenor Rd.	15.1	4.2	10.9	0	0	2.1	1.5
4 Ployart Rd.	12.1	0	12.1	0.5	2.5	9	0
5 Northy Lake	8.9	6.5	2.4	0.6	0.2	1.7	0
6 Sayer Ck.	11.7	1.7	10	1.6	0.4	6.3	0
7 Y Ditch	1.9	0	1.9	0.2	0.4	1.1	0
8 Miller Ck.	36.5	10.1	26.4	0.4	2	5.6	2.2
9 Ketty Ck.	2	0	2	0	1.8	1.8	0
10 Above Northy	8	6	2	1.5	2.2	0	0
11 R.O.W.	3	0	3	0.2	0.5	2.5	0
12 Powerline	11.2	6.6	4.6	0.3	0	0	2.5
13 Duncan Bay	8.3	5.5	2.8	0.6	0	0	0
14 Top End	6.1	0	6.1	0	0.6	0	0
Total	138.6	49.2	89.4	7.0	12.3	35.2	6.9

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APPENDIX I

Appendix Table 1. Summer coho population estimates by site and date. Fish estimates based on three pass removal method.

Appendix Table 2. Black Creek, winter fish population estimates (coho, cutthroat trout, and stickleback) by site. Fish captured by minnow traps.

Appendix Table 3. Fyke net catches (Observed) and estimates of coho smolt production (Estimate). Estimates are extrapolated from either the percentage of the channel cross section sampled (% Flow) or from percentage of marked coho recovered (% Recovery). The portion of Black Creek's smolt production passing a fyke (% Total) is the ratio of 'estimate' at a given location to the 'main fence' count for that year.

Appendix Table 1. Summer coho population estimates by site and date. Fish estimates based on three-pass removal method.

Basin	Site	Date	Estimate	SE	Coho/m^2	Coho/m
1	LAL1525	7/20/95	6	0.0	6.0	0.3
1	LAL1550	7/20/95	0	0.0	0.0	0.0
1	LAL350	7/20/95	20	0.0	20.0	1.0
1	LAL425	7/20/95	12	0.0	24.0	0.6
1	MST475	10/24/94	13	3.2	0.1	0.5
1	MST5525	10/16/94	1	0.0	0.0	0.0
1	MST6650	10/16/94	14	0.3	0.1	0.8
3	SUR1675	8/16/94	0	0.0	0.0	0.0
3	SUR2925	8/16/94	0	0.0	0.0	0.0
3	SUR900	8/16/94	0	0.0	0.0	0.0
4	PLO3175	10/24/94	0	0.0	0.0	0.0
4	PLO375	10/24/94	0	0.0	0.0	0.0
4	PLO4150	10/24/94	0	0.0	0.0	0.0
4	PLO4350	10/24/94	0	0.0	0.0	0.0
5	MST11325	10/15/94	49	3.0	0.6	2.6
5	MST11575	10/15/94	2	0.2	0.0	0.1
5	MST11775	10/14/94	32	1.8	0.3	1.4
5	MST11925	10/13/94	0	0.0	0.0	0.0
5	MST12250	10/14/94	25	2.6	0.2	1.2
6	KEL1150	10/16/94	28	3.9	1.2	1.9
6	KEL1875	8/16/94	0	0.0	0.0	0.0
6	KEL2900	8/16/94	0	0.0	0.0	0.0
6	KEL5100	8/16/94	0	0.0	0.0	0.0
6	KEL550	10/16/94	0	0.0	0.0	0.0
6	KEL900	10/16/94	15	0.4	0.5	1.4
7	PAR150	10/15/94	0	0.0	0.0	0.0
7	PAR275	10/15/94	0	0.0	0.0	0.0
7	PAR75	10/15/94	4	3.5	0.1	0.2
8	MIL100	10/12/94	0	0.0	0.0	0.0
8	MIL225	10/12/94	0	0.0	0.0	0.0
8	MIL400	10/12/94	0	0.0	0.0	0.0
8	MIL525	10/13/94	41	0.6	0.7	1.8
8	MIL625	10/12/94	92	0.5	1.3	4.9
8	MIL900	10/12/94	74	1.6	0.9	3.7
9	HEN175	10/13/94	1	0.0	0.1	0.2
9	HEN375	10/13/94	0	0.0	0.0	0.0
9	HEN875	10/13/94	0	0.0	0.0	0.0
10	MST14925	10/13/94	4	3.5	0.1	0.2
11	ROW450	10/17/94	5	0.0	0.1	0.2
11	ROW700	10/17/94	4	0.0	0.3	0.4
11	ROW75	10/17/94	0	0.0	0.0	0.0
12	MST20800	10/17/94	96	1.5	1.0	3.9
12	MST22050	10/17/94	35	1.0	0.6	2.8
13	MST24425	10/11/94	74	0.3	0.9	1.9
13	MST24675	10/25/94	6	0.0	0.1	0.1
13	MST24925	10/25/94	0	0.0	0.0	0.0
13	MST25175	10/25/94	2	0.0	0.0	0.0
13	MST25425	10/25/94	0	0.0	0.0	0.0

Appendix Table 2. Black Creek winter fish population estimates (coho, cutthroat trout, and stickleback) by site. Fish captured by minnow traps.

Basin	Site	Date	Traps	Coho/m	Cutt/m	Stick/m
1	EST175	2/9/95	20	0.09	0.00	3.48
1	LAL575	2/10/95	20	0.00	0.09	0.00
1	MST475	3/17/95	20	0.21	0.00	1.40
1	MST6350	3/18/94	15	0.00	0.00	0.08
1	MST6650	3/18/94	5	0.06	0.00	0.30
2	HAM1175	3/18/94	13	0.02	0.00	0.85
2	HAM2100	1/18/95	20	0.02	0.00	0.00
3	SUR1675	3/23/94	20	0.02	0.03	1.17
3	SUR2925	2/10/95	22	0.00	0.00	0.00
3	SUR3100	2/11/95	20	0.00	0.00	0.66
3	SUR4100	2/11/95	20	0.00	0.00	0.80
3	SUR650	2/11/95	20	0.00	0.00	0.06
4	PLO1775	3/25/94	20	0.05	0.00	10.37
4	PLO375	1/18/95	19	0.00	0.00	0.32
5	DIT200	3/22/97	7	0.09	0.00	0.69
5	MST11775	12/7/95	5	0.06	0.00	0.18
5	MST11925	12/7/95	8	0.00	0.00	0.34
5	MST13425	3/22/97	20	0.00	0.00	0.49
5	MST9350	3/16/94	10	0.00	0.00	1.89
5	MST9425	3/16/94	10	0.03	0.03	1.89
6	KEL1150	3/16/94	16	0.18	0.30	1.95
6	KEL1150	1/10/95	13	0.00	0.00	0.00
6	KEL1150	1/17/95	15	0.03	0.00	0.06
6	KEL1150	1/20/95	15	0.21	0.00	0.24
6	KEL1150	12/6/95	10	0.06	0.00	0.24
6	KEL1150	1/10/96	10	0.06	0.00	0.15
6	KEL1250	3/16/94	4	1.95	0.00	3.75
6	KEL1250	1/10/95	20	0.06	0.00	0.12
6	KEL1250	1/18/95	20	0.54	0.00	0.24
6	KEL1250	1/21/95	20	0.18	0.00	0.78
6	KEL1250	12/6/95	10	1.38	0.24	2.16
6	KEL1250	1/10/96	10	0.54	0.06	1.50
6	KEL1250	2/20/96	20	1.80	0.00	3.12
6	KEL1250	3/13/96	19	2.04	0.06	5.40
6	KEL3900	3/24/94	20	0.00	0.00	14.10
6	KEL4775	3/22/94	20	0.00	0.00	0.38
6	KEL5100	3/22/94	20	0.06	0.00	0.96
6	KEL5100	12/6/95	10	0.12	0.00	0.00
6	KEL5100	1/10/96	20	0.00	0.00	0.38

Appendix Table 2 (continued).

Basin	Site	Date	Traps	Coho/m	Cutt/m	Stick/m
7	PAR150	1/17/95	20	0.20	0.00	0.93
7	PAR150	1/20/95	20	0.23	0.00	0.54
7	PAR275	1/17/95	15	0.10	0.00	3.30
7	PAR275	1/20/95	15	0.22	0.00	0.28
8	MIL1425	2/9/95	20	0.00	0.00	0.26
8	MIL1600	3/25/94	20	0.00	0.00	1.70
8	MIL2000	3/8/94	20	0.26	0.03	0.51
8	MIL225	3/21/97	20	0.02	0.00	0.15
8	MIL2325	2/9/95	20	0.05	0.02	0.95
8	MIL2500	2/9/95	20	0.15	0.00	0.08
8	MIL4050	3/26/94	20	0.00	0.00	1.17
8	MIL625	3/21/97	20	0.25	0.04	0.29
8	MIL7600	3/9/94	20	0.00	0.00	0.84
9	HEN175	1/18/94	20	0.45	0.03	0.78
9	HEN175	1/21/95	20	0.30	0.00	0.63
10	MAC250	3/25/94	20	0.00	0.00	4.52
10	MAC650	2/4/94	6	0.00	0.00	1.38
10	MAC850	3/23/94	20	0.00	0.00	3.75
10	MST14625	3/20/97	12	0.36	0.00	0.51
10	MST16825	3/24/94	20	0.20	0.02	1.05
11	ROW650	2/3/94	5	0.12	0.00	0.00
11	ROW700	2/3/94	10	0.27	0.00	0.00
12	DUN1500	2/20/96	10	0.03	0.00	0.81
12	DUN1700	2/20/96	10	0.00	0.00	0.30
12	DUN800	2/28/94	20	0.02	0.12	0.45
12	MST22050	3/8/94	20	0.18	0.02	0.68
13	LES400	1/10/96	5	0.10	0.00	0.00
13	LES450	1/10/96	8	0.00	0.00	0.00
13	MST22925	3/11/94	20	0.00	0.02	0.00
13	MST24425	3/8/94	10	0.03	0.06	0.00
13	MST24675	3/8/94	10	0.06	0.03	0.00
13	MST24925	3/11/94	20	0.02	0.06	0.00
13	MST28600	2/15/94	10	0.00	0.06	0.00
13	MST29825	3/10/94	17	0.00	0.30	0.00
14	CUT325	3/11/94	20	0.00	0.27	0.00
14	MST30150	2/28/94	20	0.00	0.50	0.00
14	MST30400	2/24/94	20	0.00	0.12	0.00
14	OYS125	3/11/94	20	0.00	0.11	0.00
14	TOP250	2/23/94	20	0.00	0.09	0.00

Appendix Table 3. Fyke net catches (Observed) and estimates of coho smolt production (Estimate). Estimates are extrapolated from either the percentage of the channel cross section sampled (% Flow) or from percentage of marked coho recovered (% Recovery). The portion of Black Creek's smolt production passing a fyke (% Total) is the ratio of 'estimate' at a given location to the 'main fence' count for that year.

Location	Basin	Year	Observed	%Flow	%Recovery	Estimate	%Total
Main Fence		1995				18295	
Surgenor	3	1995	1				
Sayer	6	1995	43				
Y Ditch	7	1995	2				
Main Fence		1996				14178	
Lalum	1	1996	82	90%		91	0.6%
Surgenor	3	1996	95	60%		158	1.1%
Ployart	4	1996	577	40%		1443	10.2%
Sturgess	AboveMid 5	1996	61				
Sayer	6	1996	832	60%		1387	9.8%
Miller Upper	Upper 8	1996	64	50%		128	0.9%
ROW	11	1996	79	90%		88	0.6%
Main Fence		1997				76238	
Sturgess	AboveMid 5	1997	10132	30%		33773	44.3%
Sayer	6	1997	543		10%	5270	6.9%
Miller Lower	8	1997	439		23%	1877	2.5%
Ketty	9	1997	27	70%		39	0.1%
Northy	Above 10	1997	7869		46%	17215	22.6%
Upper	Above 12	1997	222	40%		555	0.7%

APPENDIX II – (unnumbered pages 35-48)

Map 1. Black Creek, Location, Watershed Boundary, and 14 Sub-basins.

Map 2. Black Creek, Land Use.

Map 3. Black Creek, Summer Salmonid Habitat.

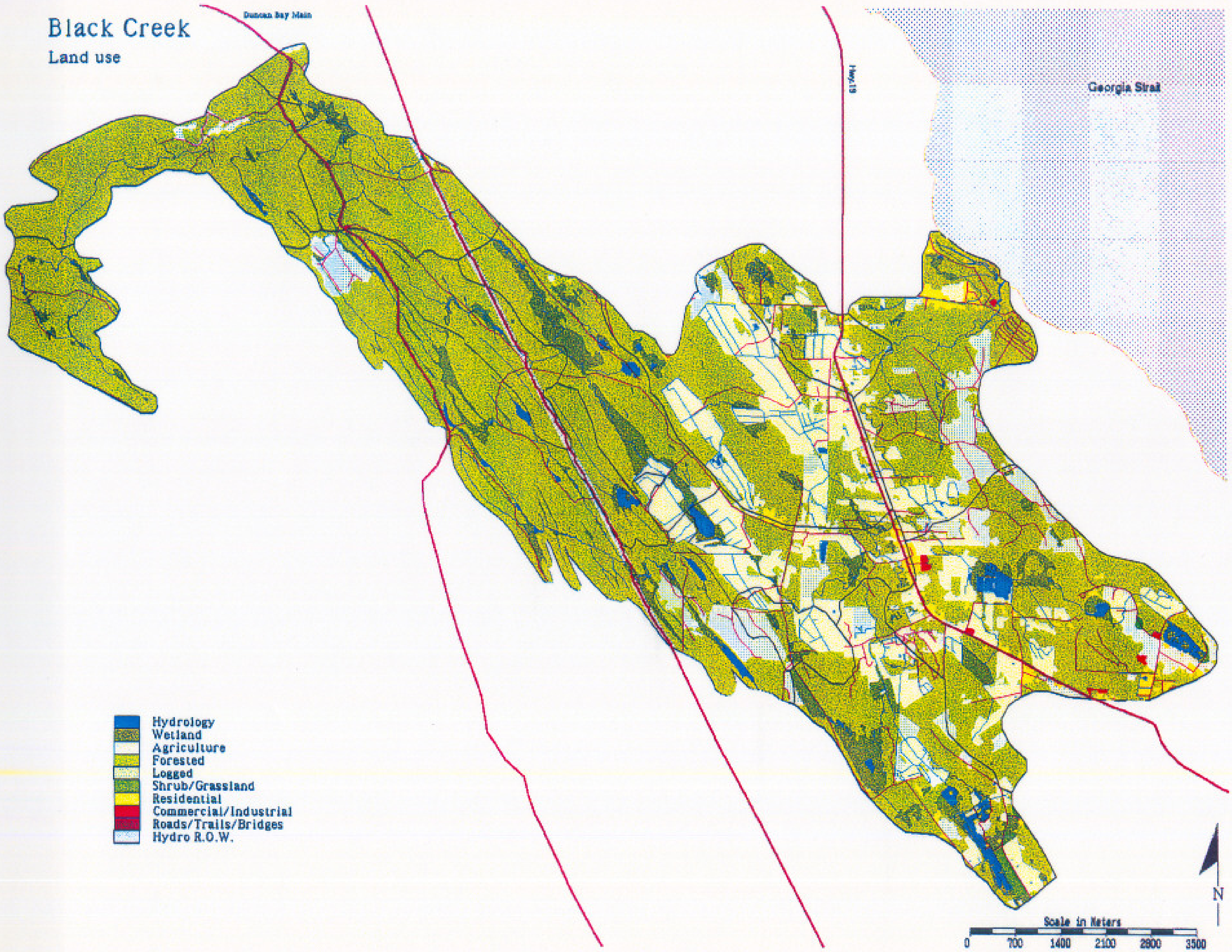
Map 4. Black Creek, Winter Salmonid Habitat.

Map 5. Black Creek, Current Utilization of Spawning Habitat (1989-1994).

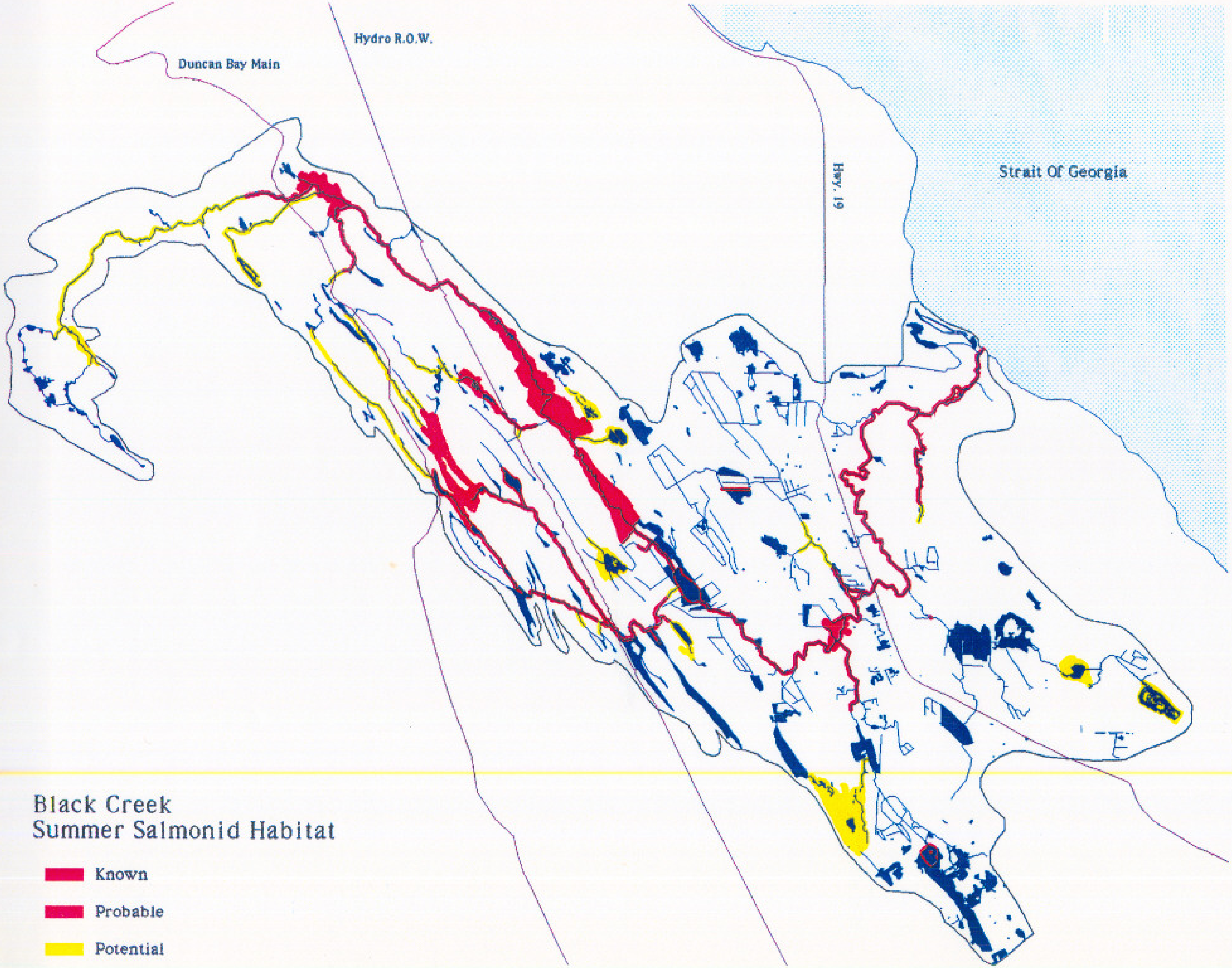
Map 6. Black Creek, Historic Spawning Locations (Hamilton, 1978).

Map 7. Black Creek, Hydrology and Location of Fyke Nets.

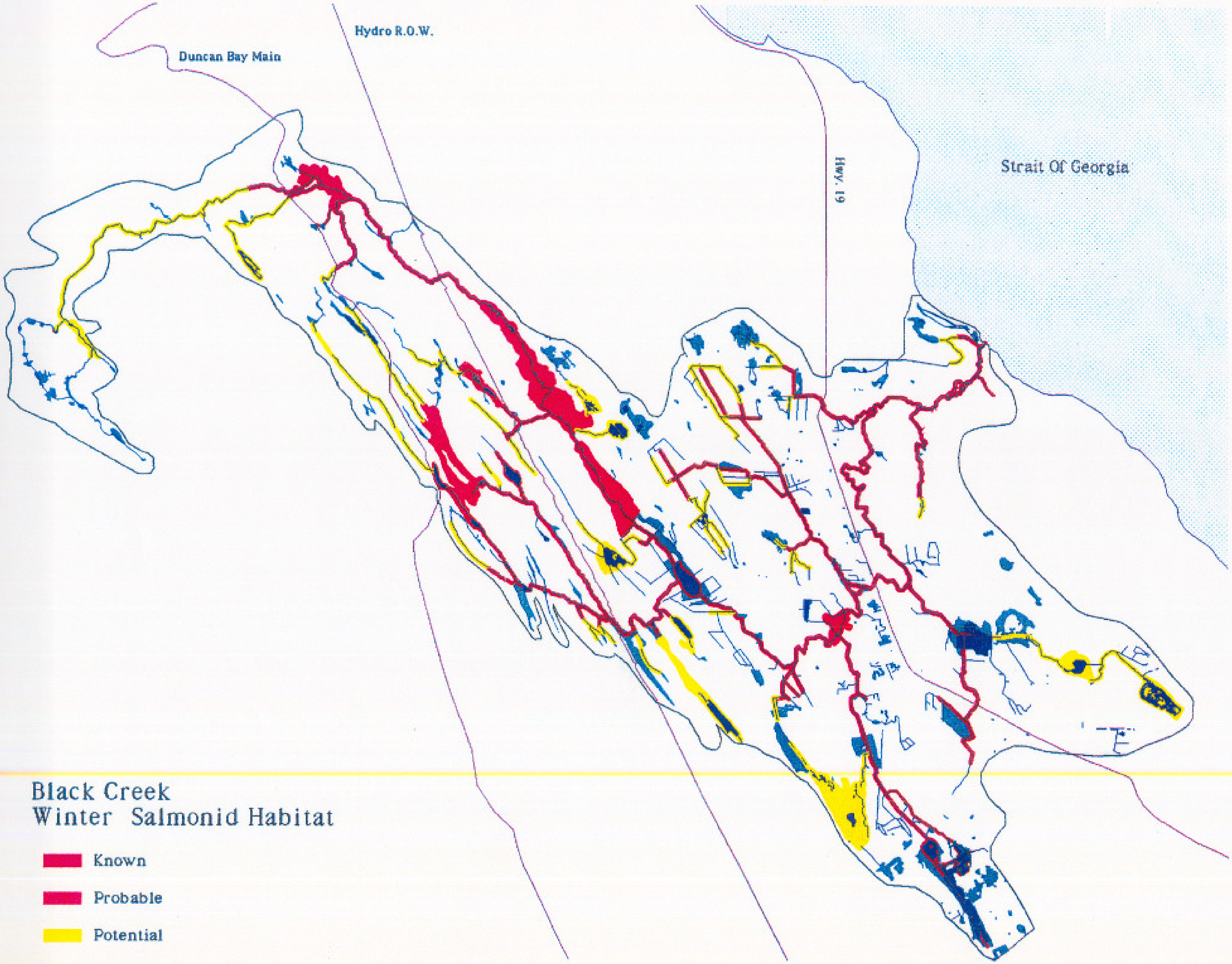

Hydro R.O.W.
Duncan Bay Main
Hwy.19
Georgia Strait
1
2
3
4
5
6
7
8
9
10
11
12
13
14
N
South Coast British Columbia
Including Vancouver Island



Black Creek
Land use
Duncan Bay Main
Hwy.19
Georgia Strait
Hydrology
Wetland
Agriculture
Forested
Logged
Shrub/Grassland
Residential
Commercial/Industrial
Roads/Trails/Bridges
Hydro R.O.W.
Scale in Meters
0
700
1400
2100
2800
3500
N

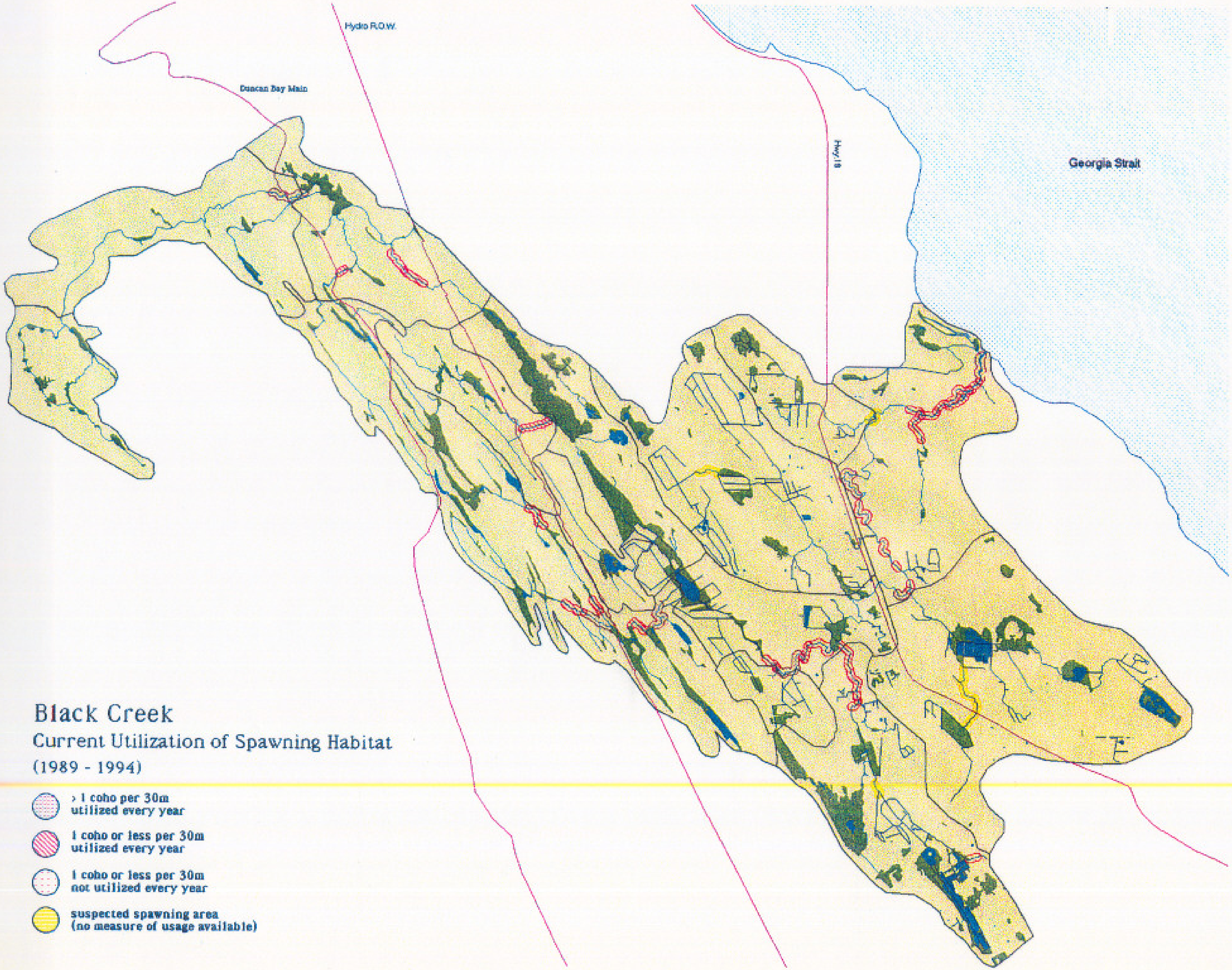


Black Creek
Summer Salmonid Habitat



Black Creek
Winter Salmonid Habitat

- Known
- Probable
- Potential



Black Creek

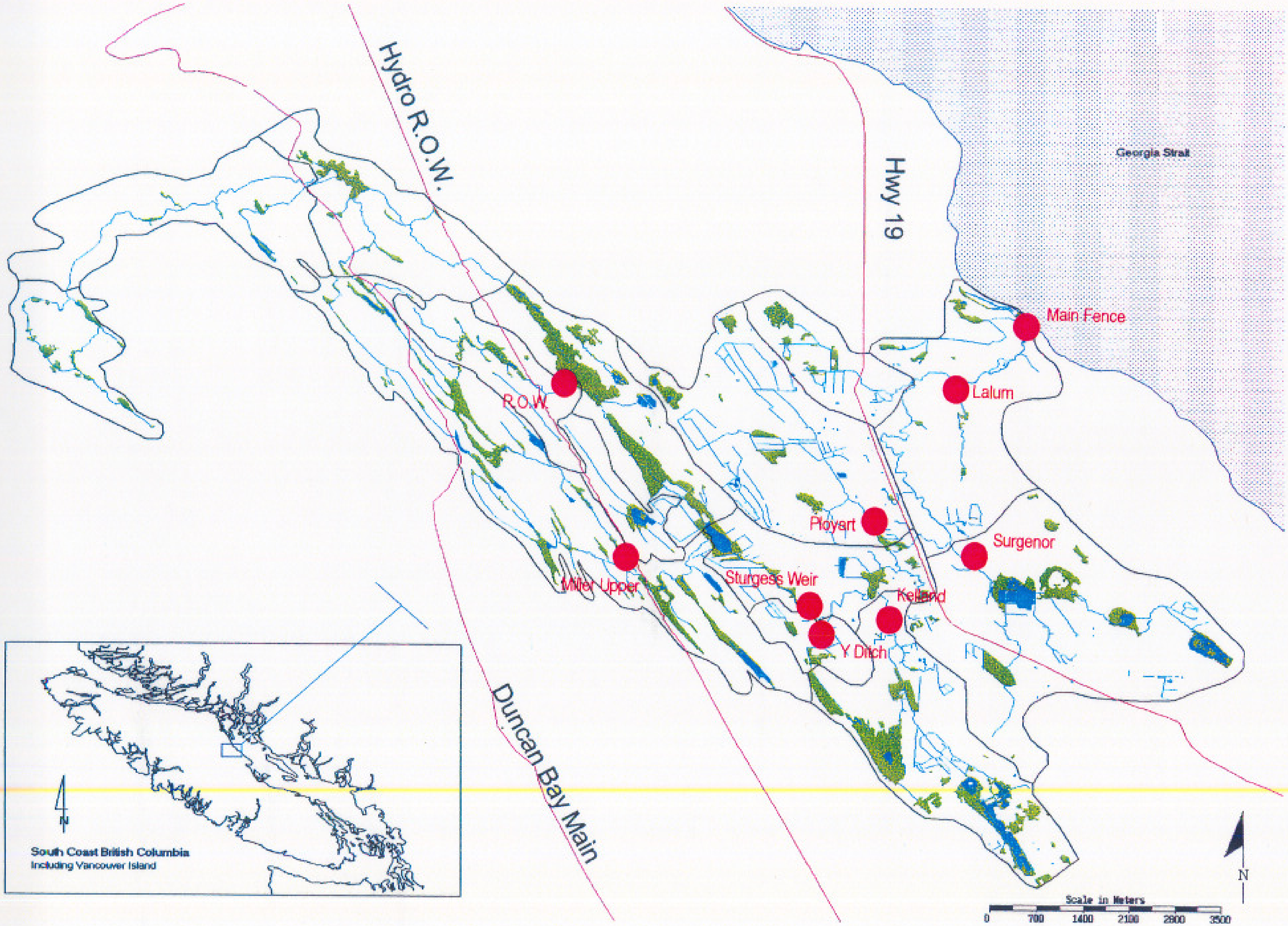
Current Utilization of Spawning Habitat

(1989 - 1994)

Black Creek
Historic Spawning Locations

(Hamilton, 1978)

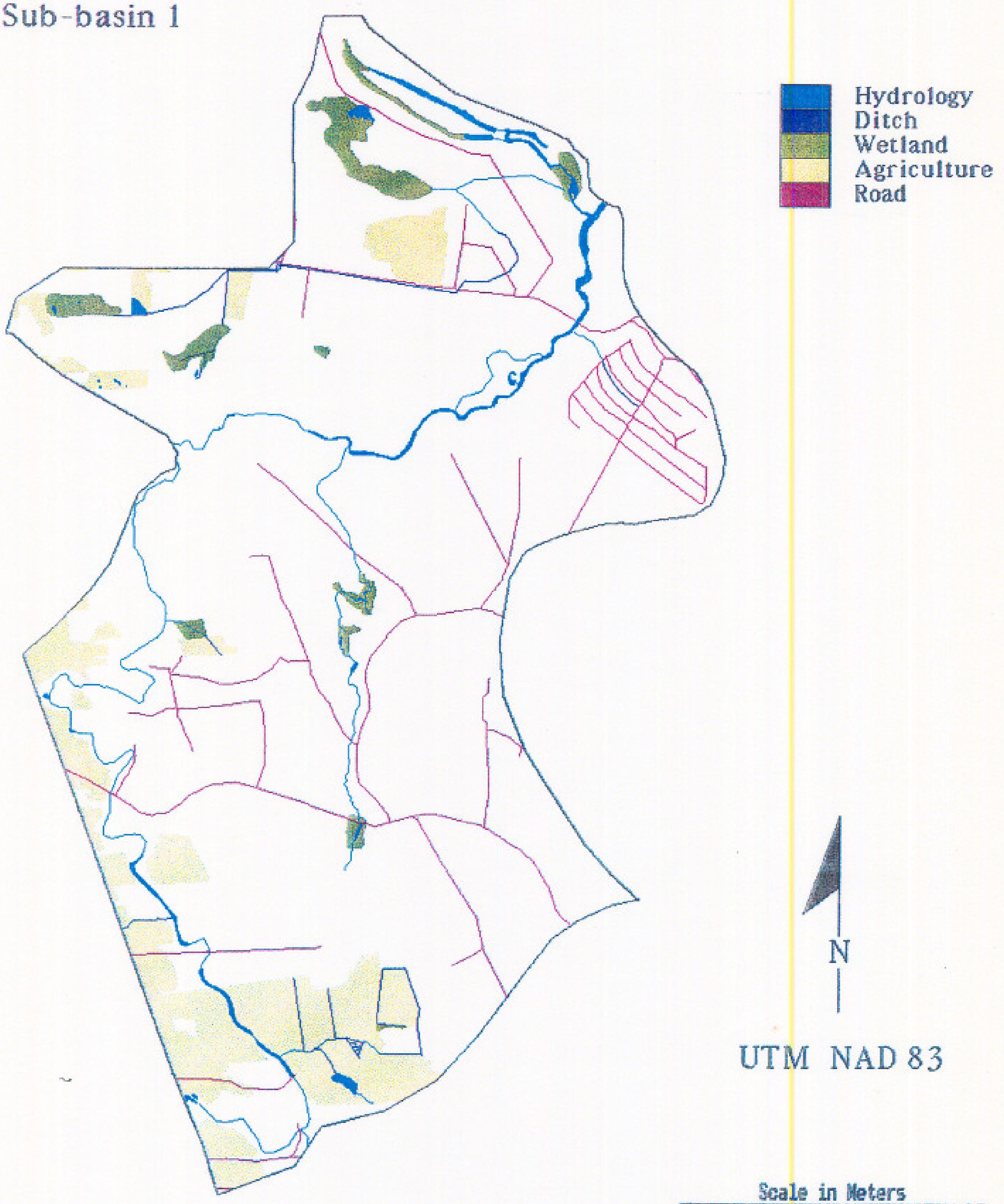
- > 1 coho per 30m utilized every year
- 1 coho or less per 30m utilized every year
- 1 coho or less per 30m not utilized every year

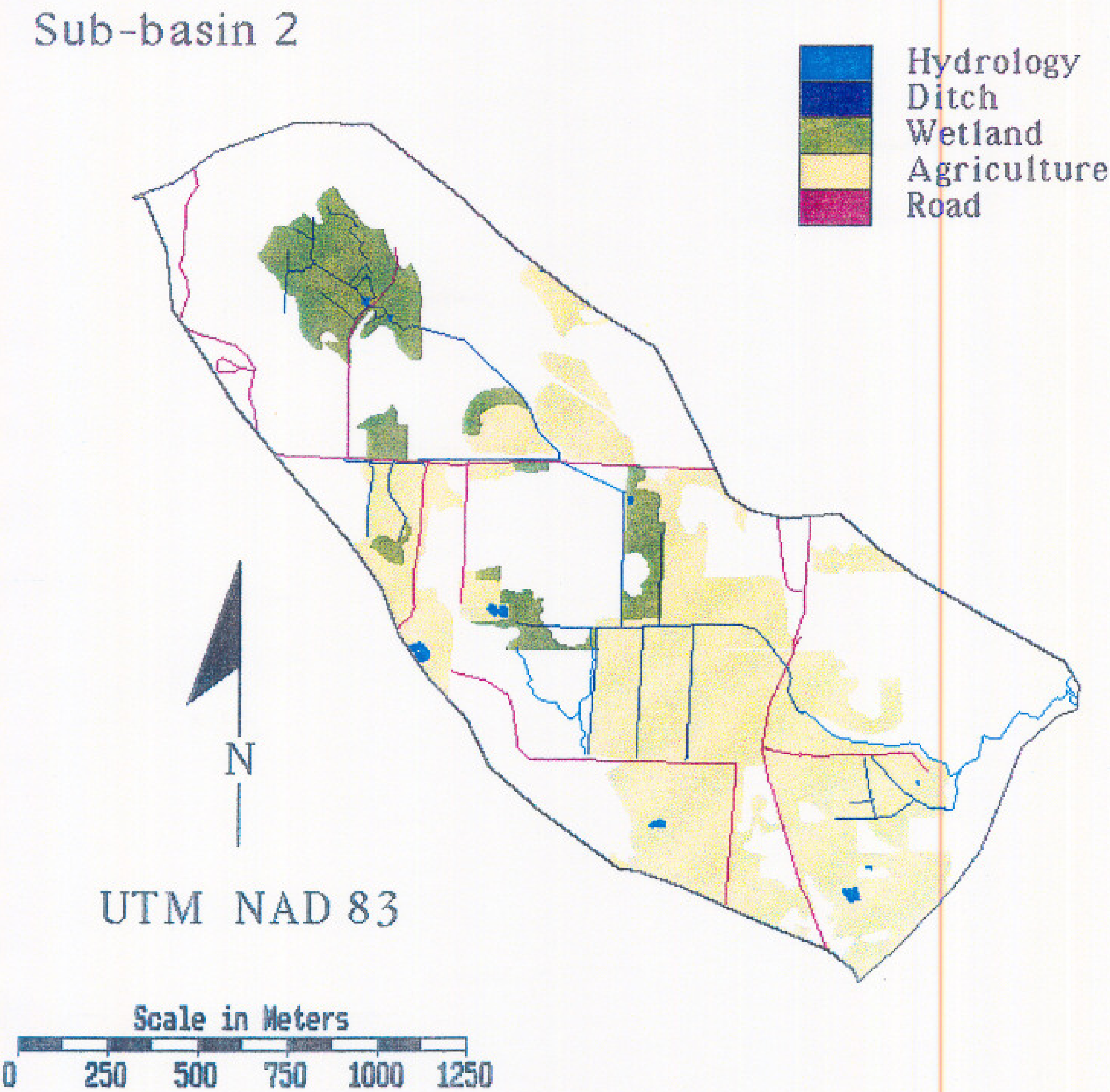


Georgia Strait
Hwy 19
Hydro R.O.W.
Duncan Bay Main
Main Fence
Lalum
Ployart
Surgenor
R.O.W.
Miller Upper
Sturgess Weir
Kelland
Y Ditch
N
Scale in Meters
0
700
1400
2100
2800
3500
N
South Coast British Columbia
Including Vancouver Island

APPENDIX III – (unnumbered pages 51-75)

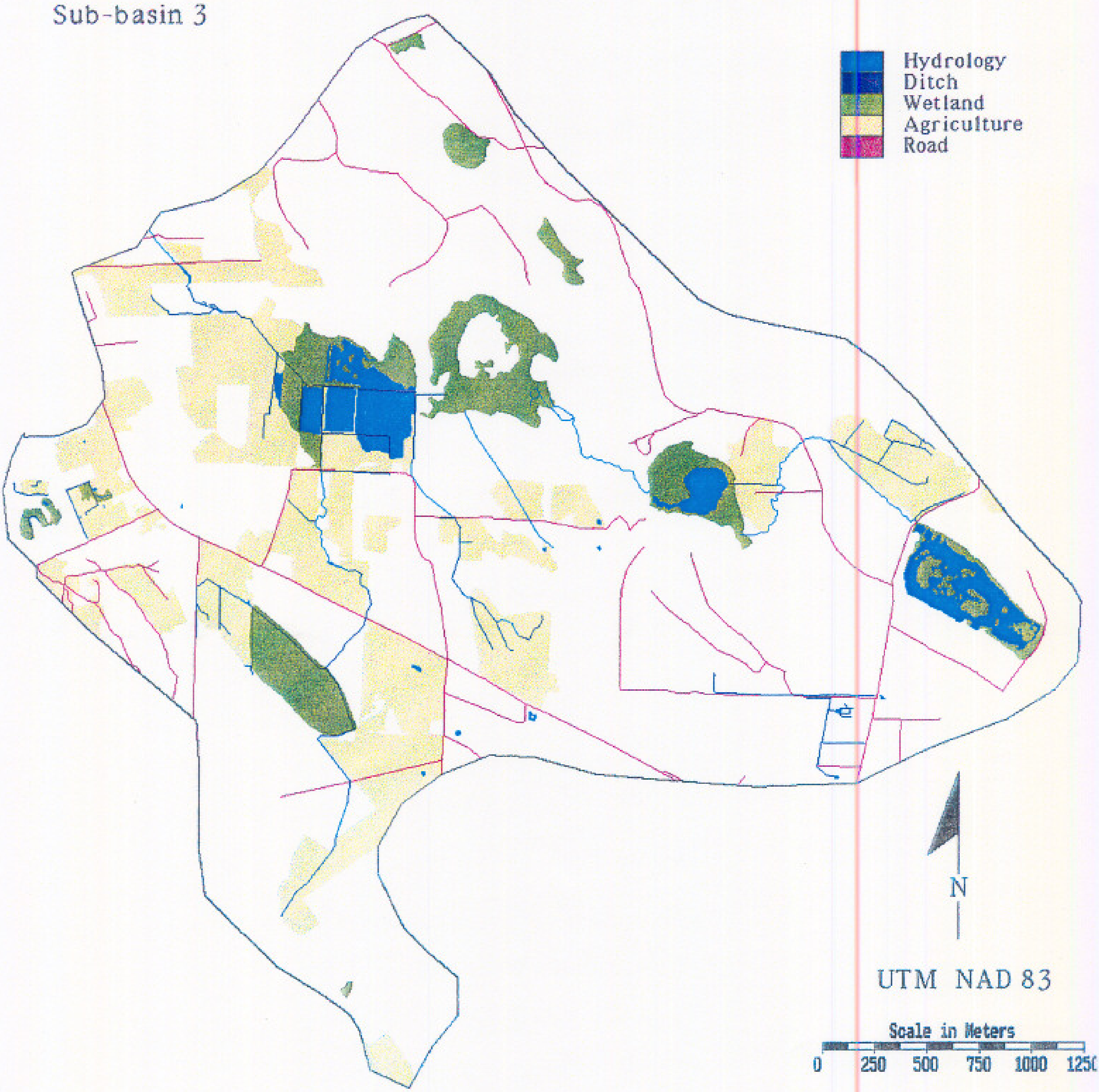
Sub-basin 1

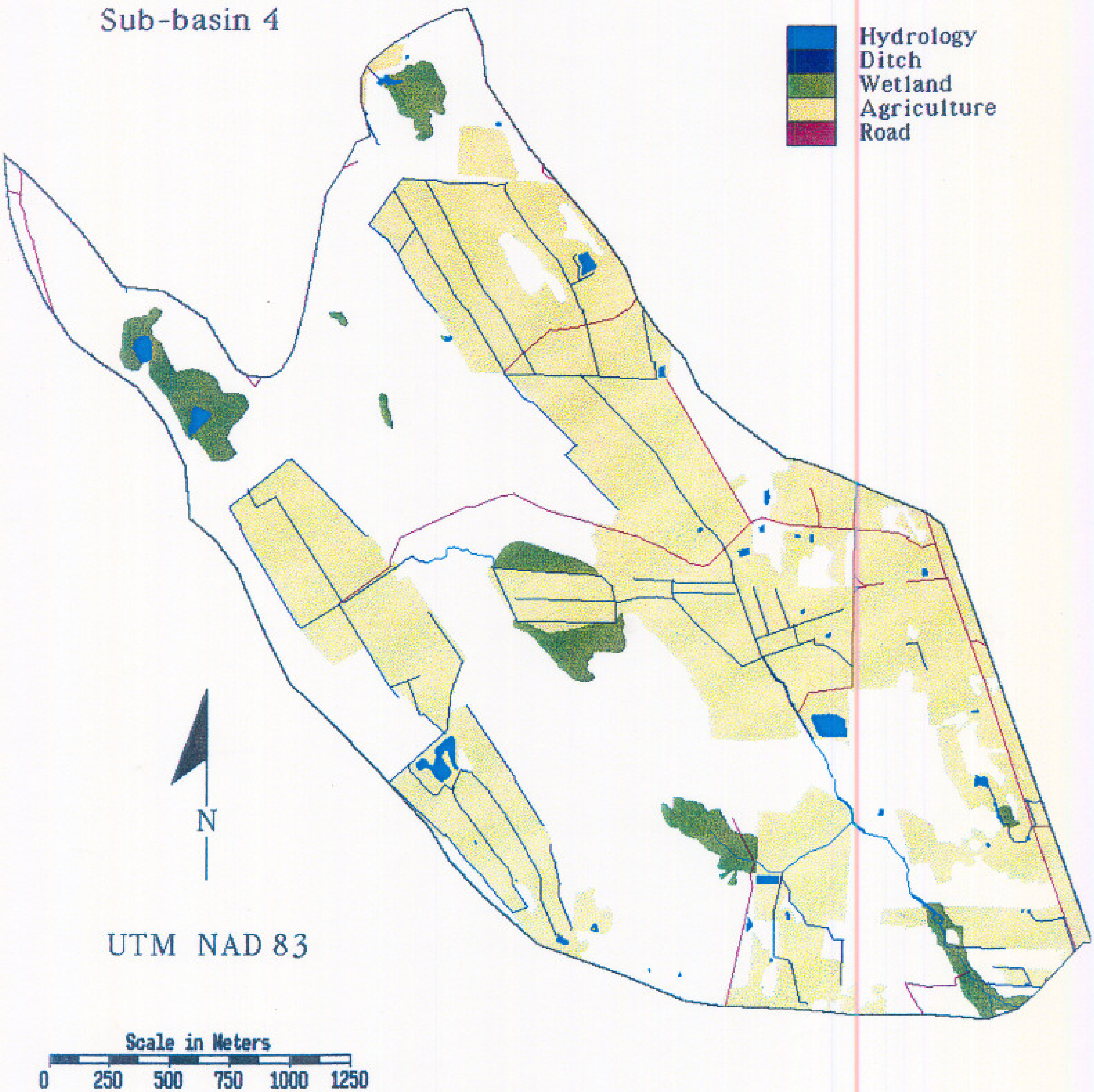

Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250



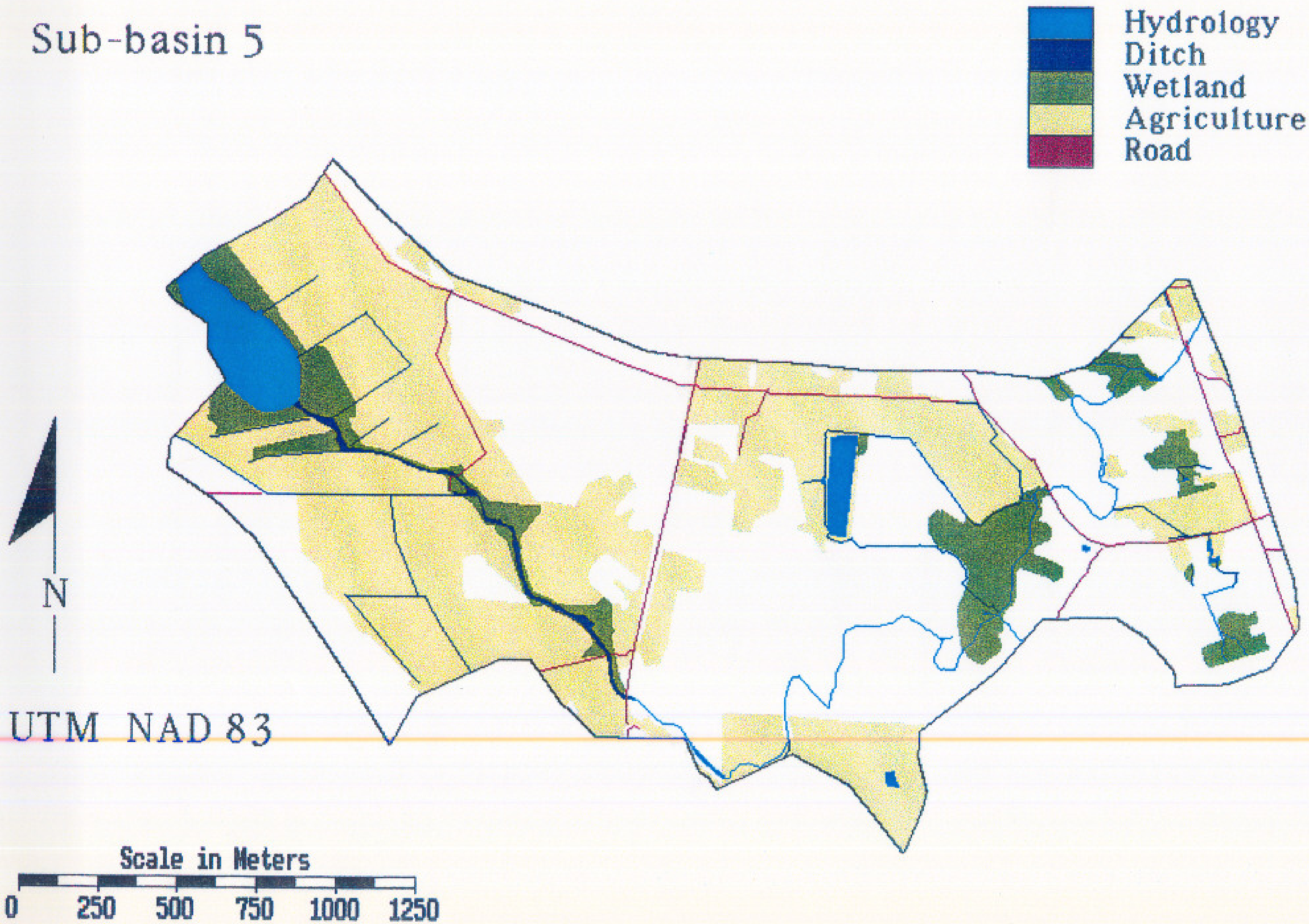
Sub-basin 2
Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250

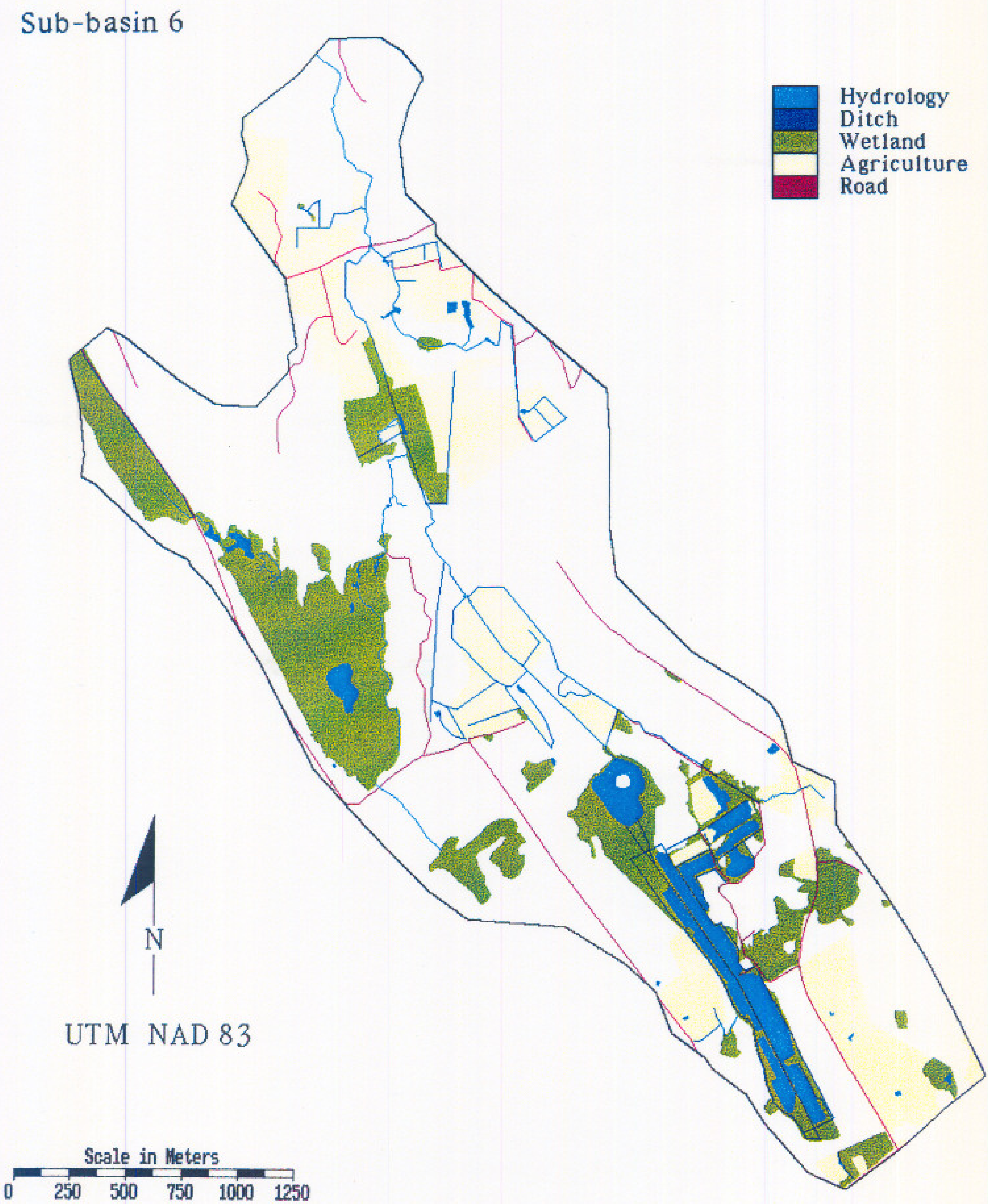
Sub-basin 3


Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250

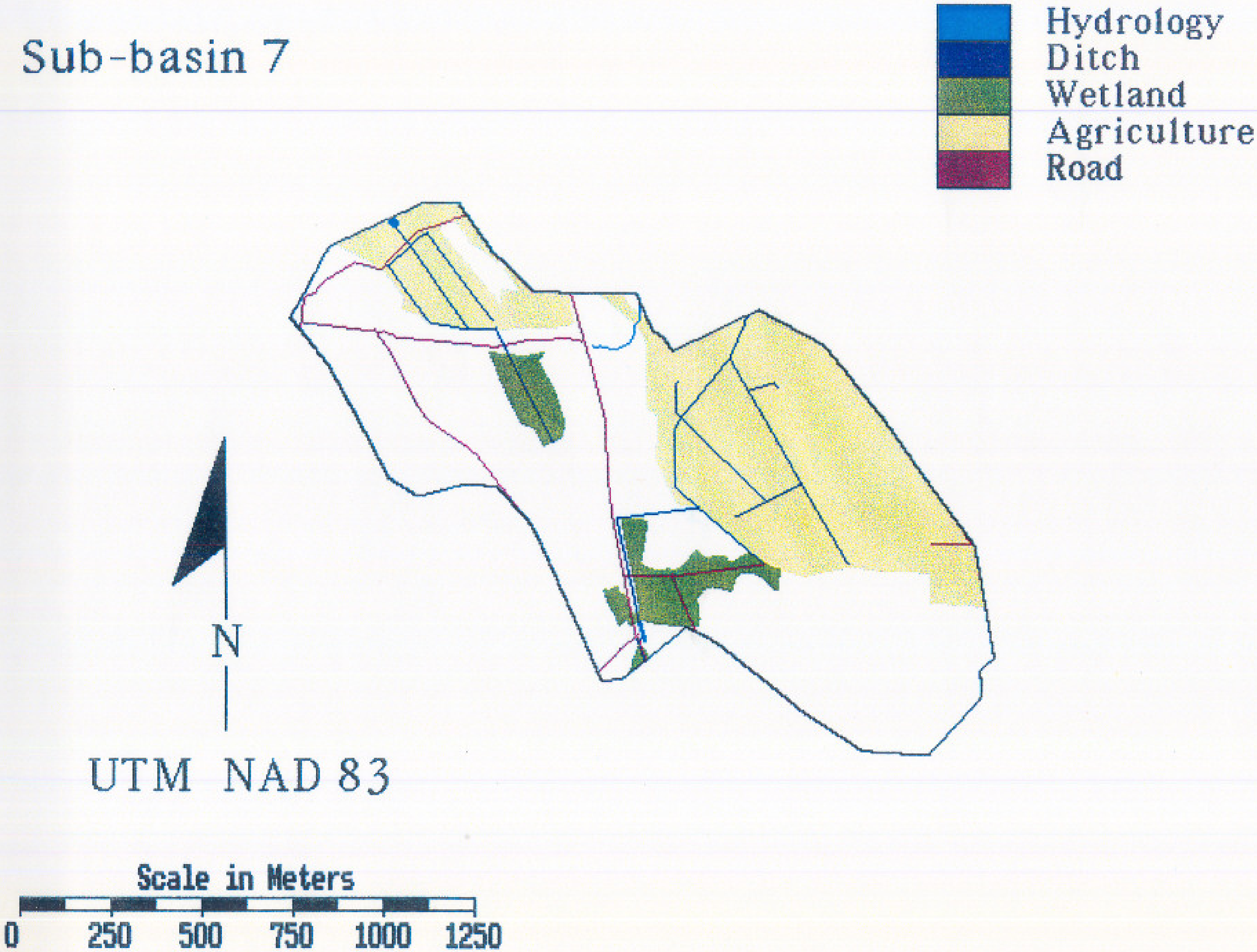


Sub-basin 4
Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250

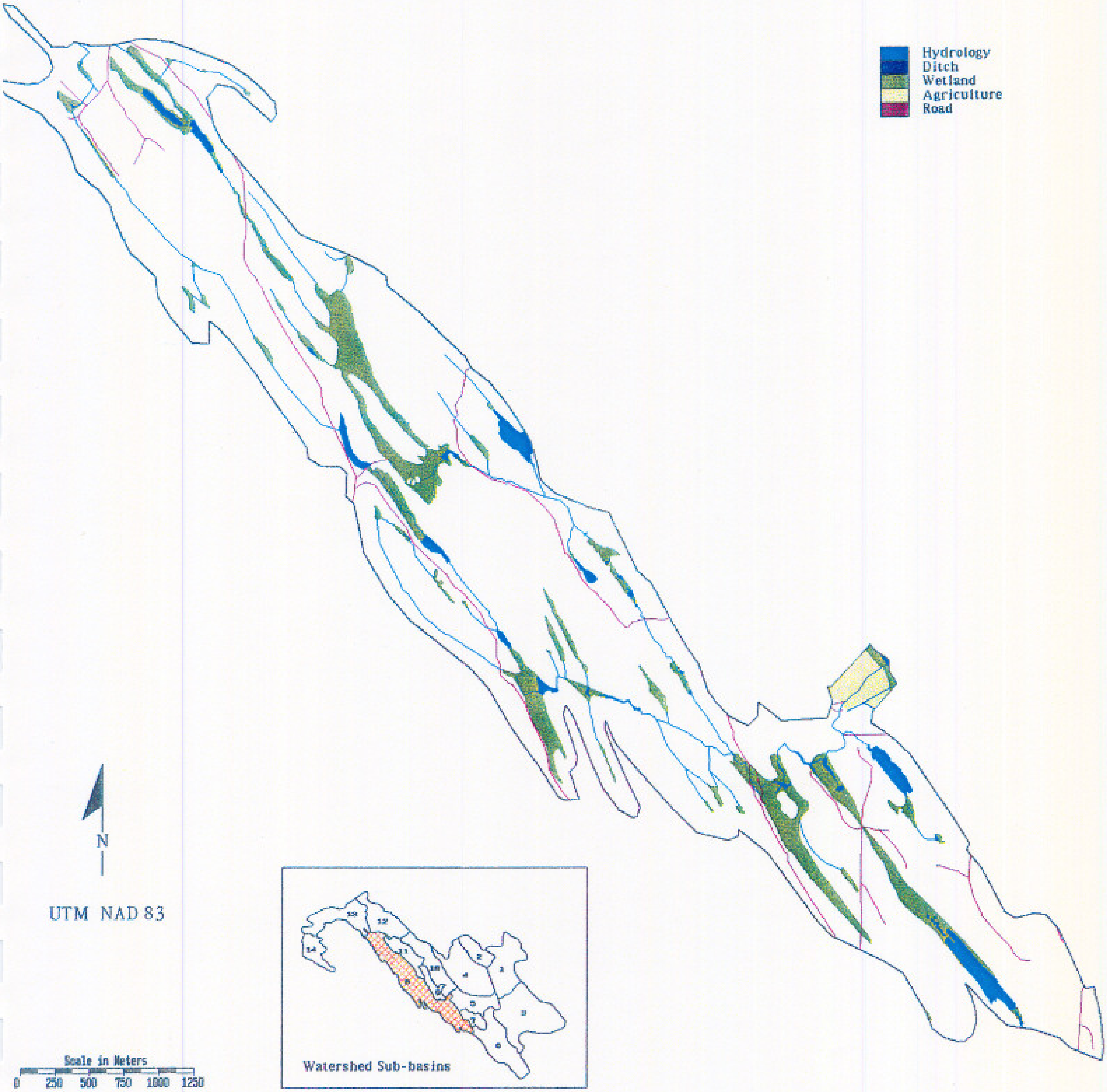

Sub-basin 5
Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250

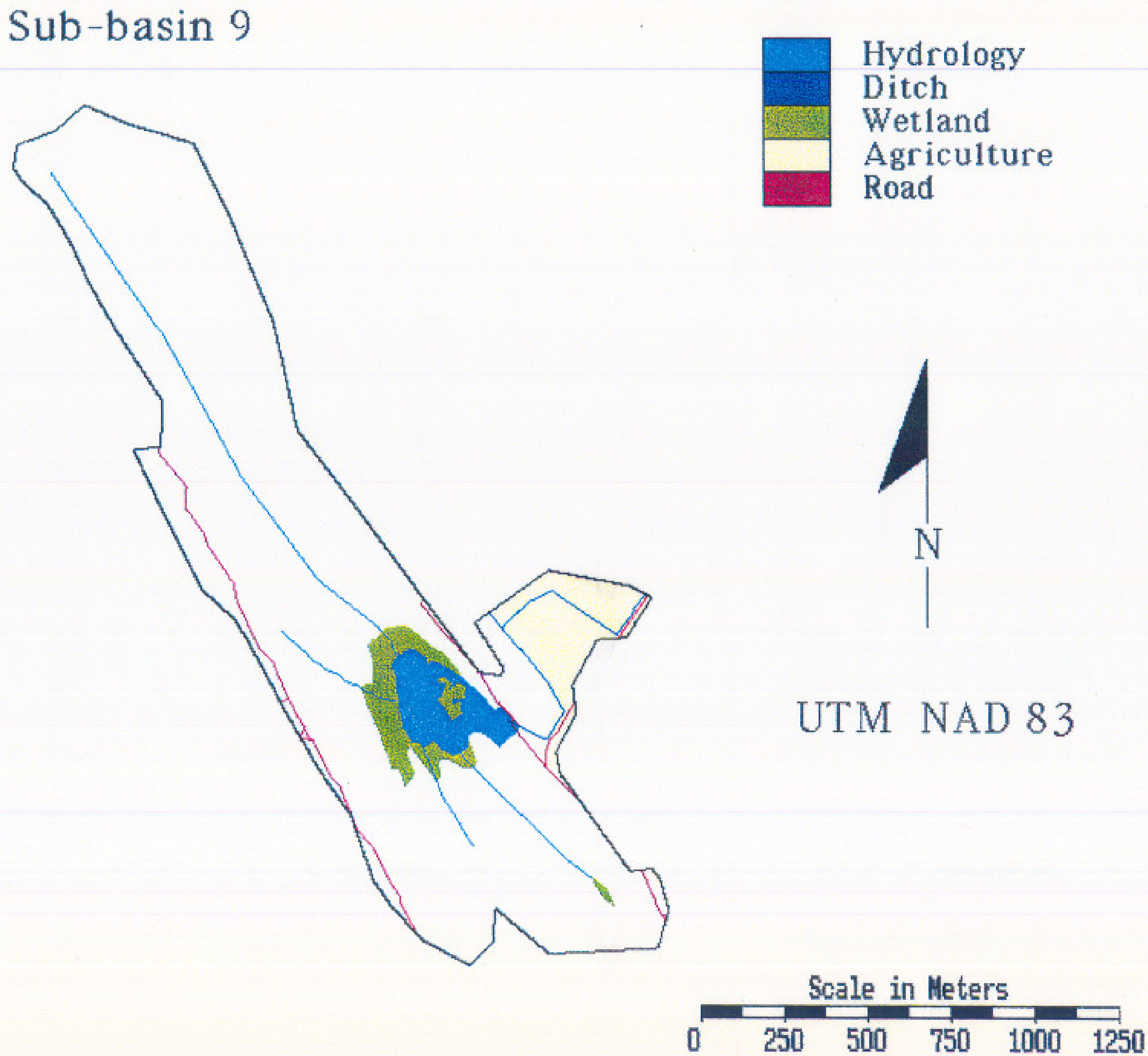


Sub-basin 6
Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0 250 500 750 1000 1250

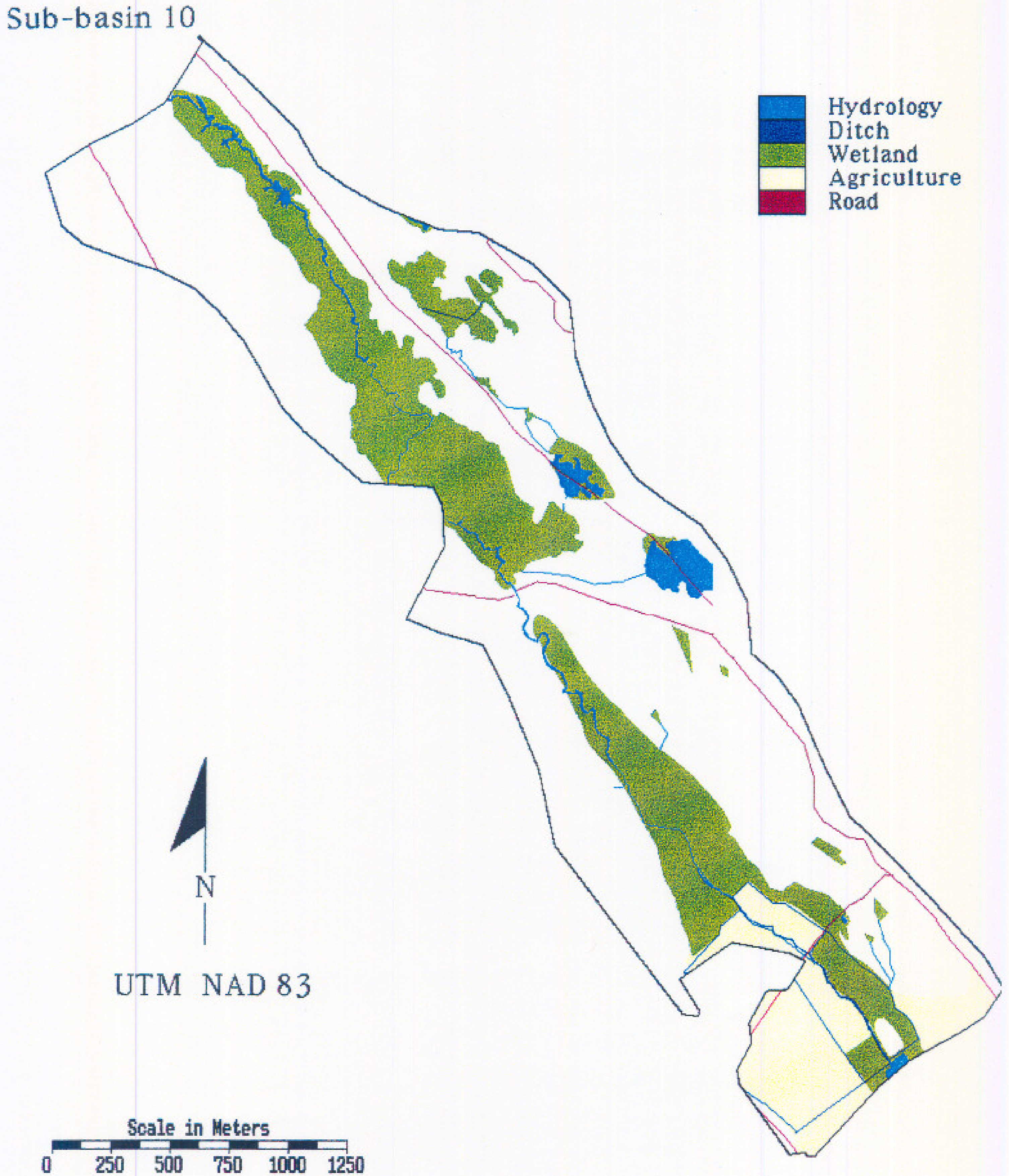

Sub-basin 7
Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250

Sub-basin 8

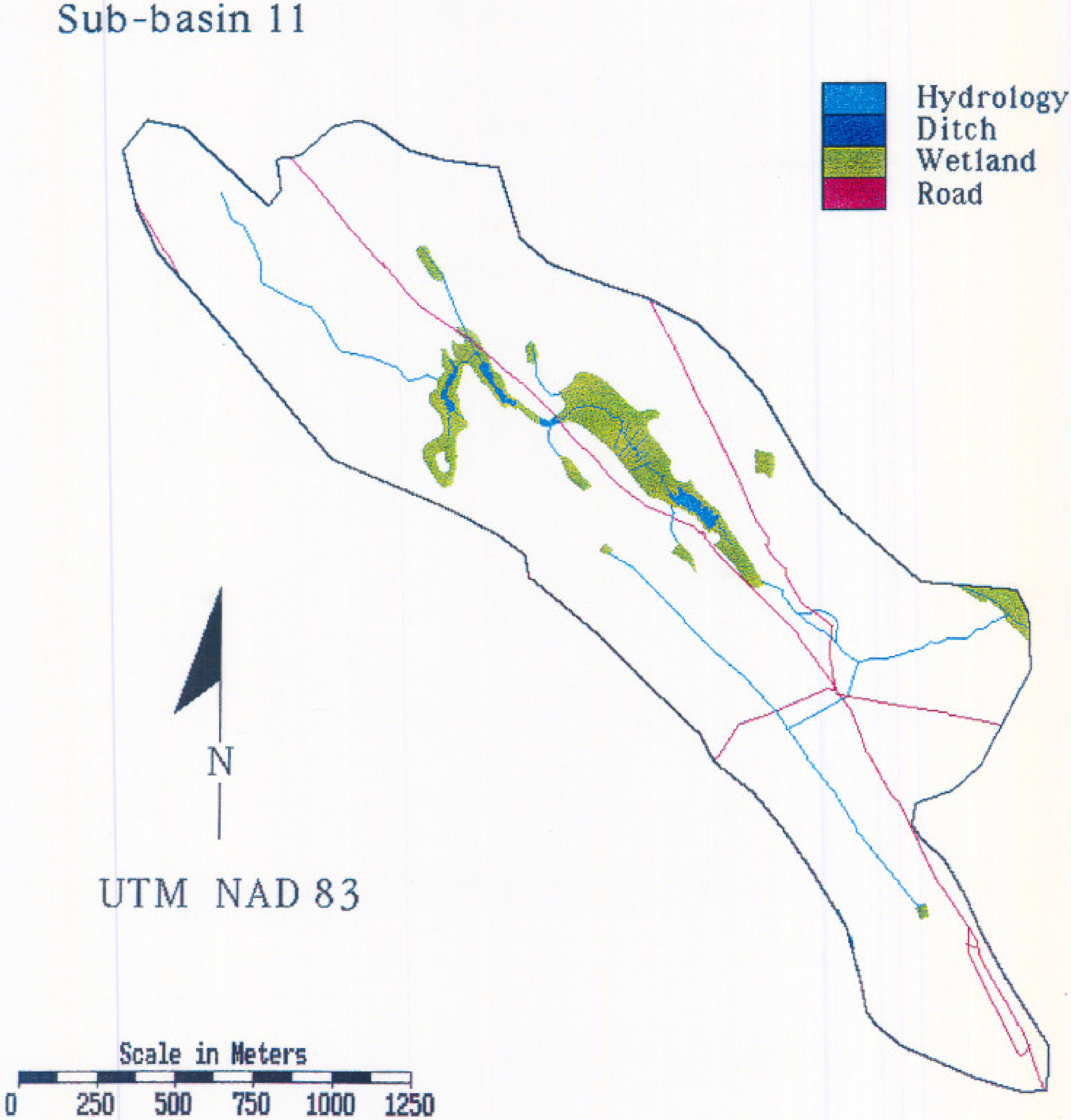

Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0 250 500 750 1000 1250
Watershed Sub-basins

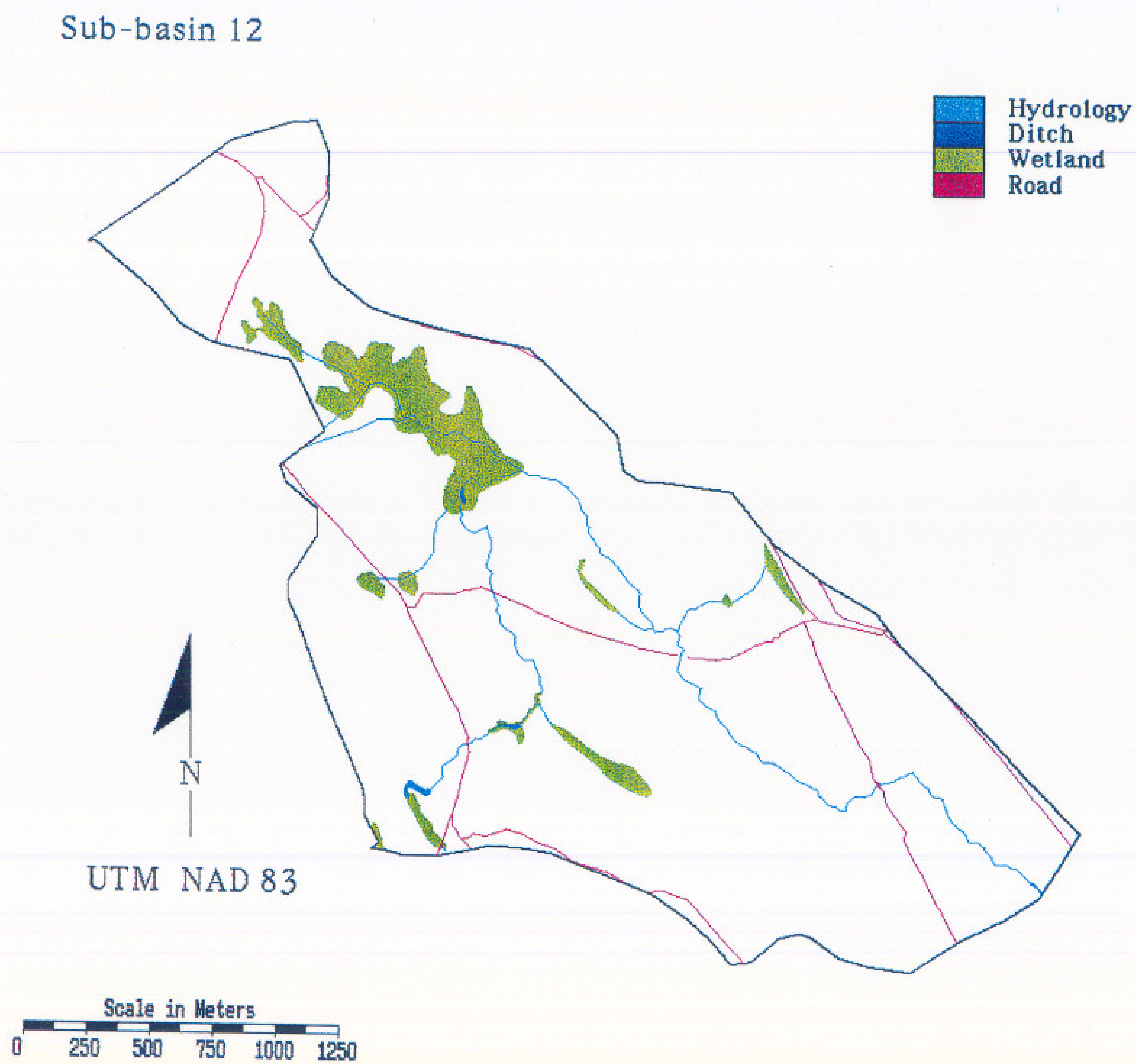


Sub-basin 9
Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250



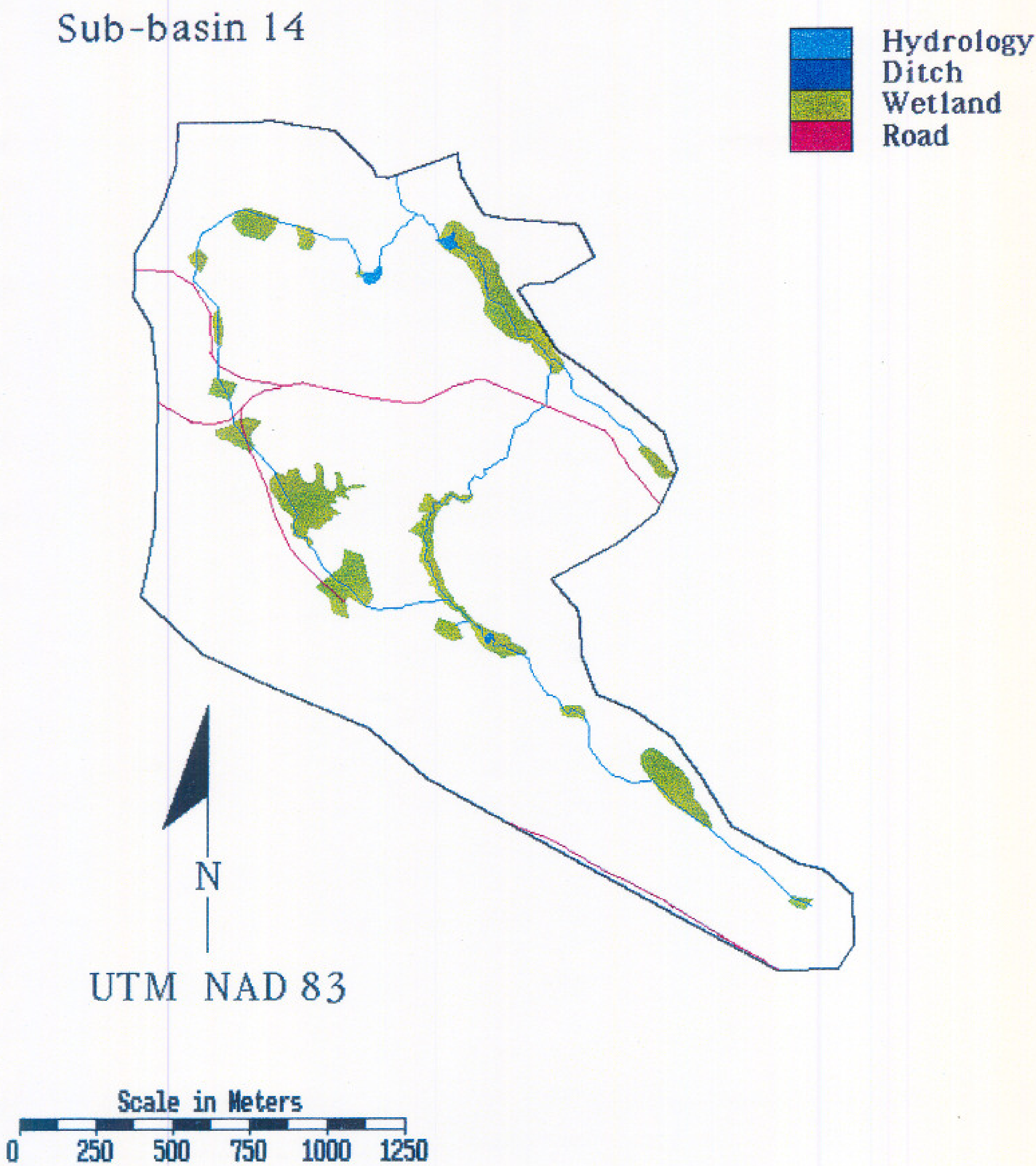
Sub-basin 10
Hydrology
Ditch
Wetland
Agriculture
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250


Sub-basin 11
Hydrology
Ditch
Wetland
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250


Sub-basin 12
Hydrology
Ditch
Wetland
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250

Sub-basin 13


Hydrology
Ditch
Wetland
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250


Sub-basin 14
Hydrology
Ditch
Wetland
Road
N
UTM NAD 83
Scale in Meters
0
250
500
750
1000
1250